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DESIGN OF A MOBILE HEALTH MONITORING VIRTUAL HUMAN APPLICATION AND EMPIRICAL EVALUATION OF THE EFFECTIVENESS OF THE INTERACTIVE VIRTUAL HUMAN ON PRESENCE, HEALTHCARE OUTCOMES AND USABILITY

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Computer Science

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by
Pratyush Singh
August 2018

Accepted by:
Dr. Sabarish V. Babu, Committee Chair
Dr. Lingling Zhang, Committee Co-chair
Dr. Larry Hodges
Dr. Andrew Robb

ABSTRACT

The study has shown that life expectancy has increased over the past few decades in all Organization for Economic Co-operation and Development (OECD) countries. The expectation of a person's life is now 80 years on average, which is 10 years more than 1970 [1]. This increase in expectation in today's busy lifestyle calls for serious health monitoring tools. Our overall project aims to identify an efficient and cost-effective approach to increase the engagement of low-income patients in an effort to strengthen communication with doctors, nurses, and other care providers to improve health outcomes, quality of life (QoL) and reduce hospital readmission rates. Virtual humans (VH) are tools that are being efficiently used in the medical field. Furthermore, technology advances in the mobile applications arena provide an opportunity to use them efficiently as healthcare assistants in these devices. Although there are studies that have tested VH on mobile platform, but to the best of our knowledge none have tested the impact of VH over a period of three weeks. Taking this notion into consideration, we created a study that analyzes and compares the impact of a mobile phone application intended to provide healthcare assistance to patients. For this investigation, we designed and performed a between-subjects investigation to compare the impact on the user's health behaviors and satisfaction while using textual over a virtual human health assistant application. The experiment consisted of comparing an Android application targeted for providing healthcare assistance to patients with two different interface designs: namely, a textual graphical with audio and an intelligent virtual human interface. The application used in this experiment is called "iHeartU". The interaction metaphor of the user interface module for "iHeartU" features an interactive

virtual assistant named "Iris". Iris is an interactive virtual human (VH) that resembles a human assistant in terms of appearance and behavior and is meant to provide natural social interaction with users of the system. Iris is capable of engaging users in a face to face dialogue through speech recognition and text-to-speech and demonstrating emotional nonverbal reactions through animations. Iris's job is to facilitate communication between users and their healthcare practitioners. Iris inquires the user on a daily basis about their current deposition regarding their eating habits, patient activity, diet intake, orientation and general demeanor. These responses are broadcasted to the server for viewing by healthcare practitioners and caregivers. On the server, the caregivers can analyze these responses by assigning the risk level for each user. The caregivers can also send a message or advice to the user which will be communicated to the user through Iris. In our empirical evaluation, we found that participants in a Virtual Human condition tend to constantly use the app while participants in textual graphical with audio condition tends to lose interest. Participant using Virtual Human interface app completed more sessions with Iris in comparison to participants using textual graphical with audio interface.

ACKNOWLEDGEMENTS

I would like to thank my advisors Dr. Sabarish V. Babu and Dr. Lingling Zhang for their close guidance throughout this project. Without their guidance, I would not have been able to get as much accomplished on this project. I would also like to thank all my team members of the Virtual Environments group for being there to provide feedback on ideas.

I would also like to thank my parents for all their love and support.

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CHAPTER ONE

INTRODUCTION

Present advancements in technology provide the option to medical doctors to adopt new paradigms for providing healthcare to their patients. Doctors can advise patients on their wellness, disease management methods or they can monitor their patient's health status using electronic devices. One area where this evolution is noticeable is the mobile field arena. Mobile phone applications (apps) have the capacity to record and store physiological and psychological information that will help doctors to measure their patient's vitals such as heart rate, weight, blood pressure, etc. Also, these apps can be used by users to self-monitor their day to day activities [2]. Additionally, mobile phone apps for health monitoring are a cost-efficient way to monitor the patients in comparison to admitting them to a hospital where patients have to physically meet with their doctors; instead, they can be monitored in their homes by this app. Finally, these healthcare apps can be highly customized according to the needs of each user or patient [8].

Moreover, one important aspect of these applications is the graphical user interface design (GUI) and the interaction metaphor or method users will employ to input their information into the app. The usability aspect of these specific types of apps needs to be intuitive and easy to use for users since most of them are not trained as medical doctors. These apps are generally more complex to understand and not easily navigable by non-health professionals [8]. This can be a problem due to the possibility that the data inputted by the user can be inaccurate or incorrect. Moreover, another variable that will have a direct incidence on the correct functioning of this system is the interaction metaphor and design [10]. One of the most accepted human-computer theories [11] states that there are two gulfs

between the user and the system: the gulf of execution and the gulf of evaluation. The gulf of execution is a difference between what user wants to do and what system allows them to do. The gulf of evaluation is a difficulty to understand the output of the system. Moreover, research seems to suggest that users like to interact with smartphones on the move and the small screen size and limited input modalities are some of the challenges while designing the interface for this application [3]. Currently, there are multiple mobile health-related apps available in different app stores for different smartphones. For example, these apps target patients with the intention of quitting smoking [12], monitoring diabetes [13], pain management [14] or for recording and keeping track of medical records [15]. Nevertheless, to the best of our knowledge, all these applications possess a typical interface that contains menus, buttons, input boxes, etc., which can be cumbersome.

An option that can provide a more intuitive interaction metaphor between the user and the application is to incorporate virtual humans (VH) as an interface. Virtual humans are digital entities that mimic human appearance and behavior. These are highly interactive, can possess artificial intelligence and can perform speech and recognize speech from the user. Virtual humans are capable of engaging users in a face to face dialogue, producing verbal and non-verbal behavior and demonstrating emotional reactions tied to the context of the conversation with the user [6, 9]. Because of available technology on smartphones, virtual human can be used as an interface in health monitoring mobile applications since they have been used successfully for clinician purposes in the past [4].

In this project, we discuss the interface of a virtual human with Smartphone applications, offering the potential to support health monitoring by their caregivers. We

designed and performed a between-subjects experiment using an Android mobile health application to evaluate the effectiveness of the interactive virtual human on the presence, healthcare outcomes and usability with a virtual human interface. The experiment includes two conditions: one that depicts a virtual human as interface and another that includes a textual audio interface.

The Android application used for the study is called "iHeartU", which we built for facilitating the communication between the users and their healthcare practitioners on health monitoring. The app asks the user periodically for feedback regarding symptoms, eating habits, patient activity, dietary intake and output, orientation and general demeanor. These responses are then broadcasted to the server at the hospital for viewing by healthcare practitioners and caregivers as consented by the patients.

In our study, the participants are recruited to use the app for three weeks for both the conditions. This study is different from other studies done in a carefully controlled environment as these participants will use the application at their home in the real world. We strongly believe that this application can have a positive impact.

CHAPTER TWO

RELATED WORK

Technological advancements in the smartphones arena revolutionized human behavior [16]. These appliances that possess higher computing capability provide affordances to users for sharing their live location via GPS, checking and sending emails, text messages, etc. Furthermore, the data gathered by these devices can be exchanged with other users in real time to significant others, stored locally in their phone memory or uploaded to the internet cloud. Moreover, smartphones use software programs (apps) that have been developed to accomplish a specific purpose [20] and that can be highly customized and tailored according to users' needs and preferences. Finally, smartphone devices have high-resolution display screens and features such as high-quality cameras and recording devices. All these qualities make these devices to be portrayed as a personal computer rather than a phone [17].

The medical field embraced the smartphone device for providing healthcare assistance and advice to patients through apps [19]. The apps focused on healthcare (usually referred as mhealth apps) developed for the Android platform are calculated to be 325,000 in 2017 [18] and a market estimated at $28.32 billion in the year 2018. The mhealth app market is expected to reach $102.35 billion by 2023 [22]. This number shows the users' interest for new tools to assist them to conduct more healthier day-to-day practices or for monitoring their current health status. There is an increasing and wide variety of health apps for different purposes. For example, users can measure their blood

pressure [21], monitor their insulin level [21], meditate [24], monitor health and fitness [25] and monitor cardiac conditions [26], naming just a few.

However, despite smartphone apps' technology and several potential advantages for providing medical advice to patients, they also have limitations and potential problems [27]. One important aspect of this type of application is the usability aspect [29]. Usability expresses the capacity with which users can use a technological artifact to achieve a goal [31]. Furthermore, usability involves the user's perceived understandability, learnability, operability and attractiveness of the application. The fact that patients can collect and input information about their health, providing a simple and intuitive method for doing this is very important. Users that adopt mhealth applications usually do not possess health literacy; if the app provides a complex interface, it can lead to errors in the input process causing frustration to the user, and eventually, they might stop using the app [30]. System usability is in the continuous study, constant improvements and over the years, the usability of the apps had become more efficient to users [28].

A theory of human-computer interaction proposed by Norman et. al [32] intends to explain system usability. This theory states that there are two gulfs between the user and the system: the gulf of execution and gulf of evaluation. The gulf of execution is a degree to which the system corresponds to users' intentions or the difficulty to use the system. For example, If the person wants to take a screenshot, user will expect that it requires a pressing of screen capture button. But if the necessary action sequence involves specifying the length and width of the screen to capture then there is a gulf of execution. The gulf of evaluation arises after the user's input, the interpretation of what the system has done and

whether it is in line with the user's goal. Norman's theory states that a system is usable if users can easily bridge these two gulfs. Users do this by forming a mental representation of the way the system works. According to Norman, the mental model is formed when appropriate feedback and feedforward is provided to the user. For instance, labels on buttons functionality (feedforward) inform users what the system will do when pressed, and understandable output (feedback) allows them to see if the system actually did what they wanted.

An alternative to the classical graphical user interfaces is virtual humans or agent-based interfaces [50]. This type of system does not have the typical graphical user interface such as buttons, menus, sliders, text fields and scrollbars, etc.; instead, users interact with virtual humans by speech or gaze, to name a few. Furthermore, the usability degree of agent-based interfaces will depend on the success users bridge between the virtual human cues in terms of appearance and language (feedforward) and the actual system capabilities provide (feedback).

Virtual humans provide a more natural interaction to users. These are synthetic characters that have human-like appearance [34], perform active and passive animations [35] and can express themselves both verbally and non-verbally [36]. VHs can interpret the user's speech and react according to the context of the conversation. All these capabilities that virtual human possess are used by simulation to treat patients that suffer from post-traumatic stress disorder [37], patients that suffer from fear of heights [38], patients with public speaking anxiety [39] or for medical training [40], to name a few. Likewise, virtual humans have been used as healthcare assistants in virtual reality

simulations. VHs could be used as the digital actor that users interact with that portray simulated doctors or as training or education tools. They can represent human-like interfaces that can interview users about their physical or mental status to help them overcome depression such as “Simsensei” [43]. This system captures, real-time, the user’s gaze, facial expressions and emotions, and reacts accordingly, giving advice to users. Virtual humans could monitor the environment through a set of sensors and act like health care professionals to remind patients of their health needs. Currently, VHs possess the appearance and behavior fidelity to a point where they can be adopted as useful tools for multiple purposes and multiple fields, including clinical and research applications.

Furthermore, virtual humans’ interfaces can provide a better and more engaging experience for the users. Researchers suggest that anthropomorphic embodied interfaces can be more attractive and more engaging to the user [44]. Users that interact with anthropomorphic interfaces tend to perceive them as human-like and as a social entity [45]. This phenomenon can be hypothesized considering the CASA (Computer are Social Actors) concept. This paradigm states that people make social inferences about computer artifacts while using them [46]. Moreover, the effect that anthropomorphic interfaces have on the users can affect other levels such as similarity-attraction [47], homophily [48] and social identity [49]. The similarity theory states that a user’s perception of similarity with another person would result in the person’s more positive overall assessment. The homophily concept states that the demographic similarity among people would result in better communication and a more comfortable interaction. Finally, the social identity model suggests that membership in a group confers a social identity that spawns a self-

categorization process that exacerbates in-group similarities and worsens out-of-group differences. All of these aspects of an anthropomorphic interface can make it more natural and engaging to the user.

Present smartphone technology provides affordances to adopt agent-based interfaces. Current computing power, advancements in artificial intelligence, speech recognition and machine learning provide the affordances to adopt agent-based interfaces into smartphones applications. Despite the current technological advances, to the best of our knowledge, there is one smartphone application that presents a virtual agent for healthcare purposes as an interface for a smartphone application for Android [42]. However, this system is focused for commercial purposes with no study. There is a study done to test the effect of an animated virtual character on mobile chat interactions [52] that suggest that people tend to engage more when they interact with a 3D animated virtual human that averts its gaze, compared to an animated virtual human that does not avert its gaze, a static image of a virtual character, or an audio-only interface. However, to the best of our knowledge none have tested the impact of VH for the health care application over a period of three weeks.

CHAPTER THREE

EXPERIMENT DESIGN

“iHeartU”, a smartphone application (app), was designed to identify an efficient and cost-effective approach to increase the engagement of low-income patients. This was done in an effort to strengthen communication with doctors, nurses, and other care providers to improve health outcomes, quality of life (QoL) and reduce hospital readmission rates. We plan to achieve this goal by developing a virtual-human assisted mobile self-management application (“iHeartU”).

SYSTEM ARCHITECTURE

The “iHeartU” app is an Android smartphone application which includes the following modules: core processing, data gathering, user interface, speech recognition, text-to-speech, voice recording, user model, data storage, reporting and online central repository/server. These modules are further summarized in Fig. 3-1 in a simplified manner.

The core processing module runs as the background process of the application logic of the system, updating the data storage component with patient data and sending information frequently to a server that could be viewed by caregivers and clinicians via a web-based application. The core processing module refers to the user model for keeping a track of patient preferences, logging of patient inputs and patient progress, which are stored locally by the data storage module and frequently appended to the patient records in the hospital via the reporting modules. The user interface module is the interface between the

patient and the “iHeartU” application, and it inquires the user through text-to-speech module from time to time to request for subjective input regarding symptoms, sleep habits, patient activity, diet intake and output, medication, orientation and general demeanor. User interface receives these inputs from the user through a data gathering module which uses speech recognition and voice recording modules.

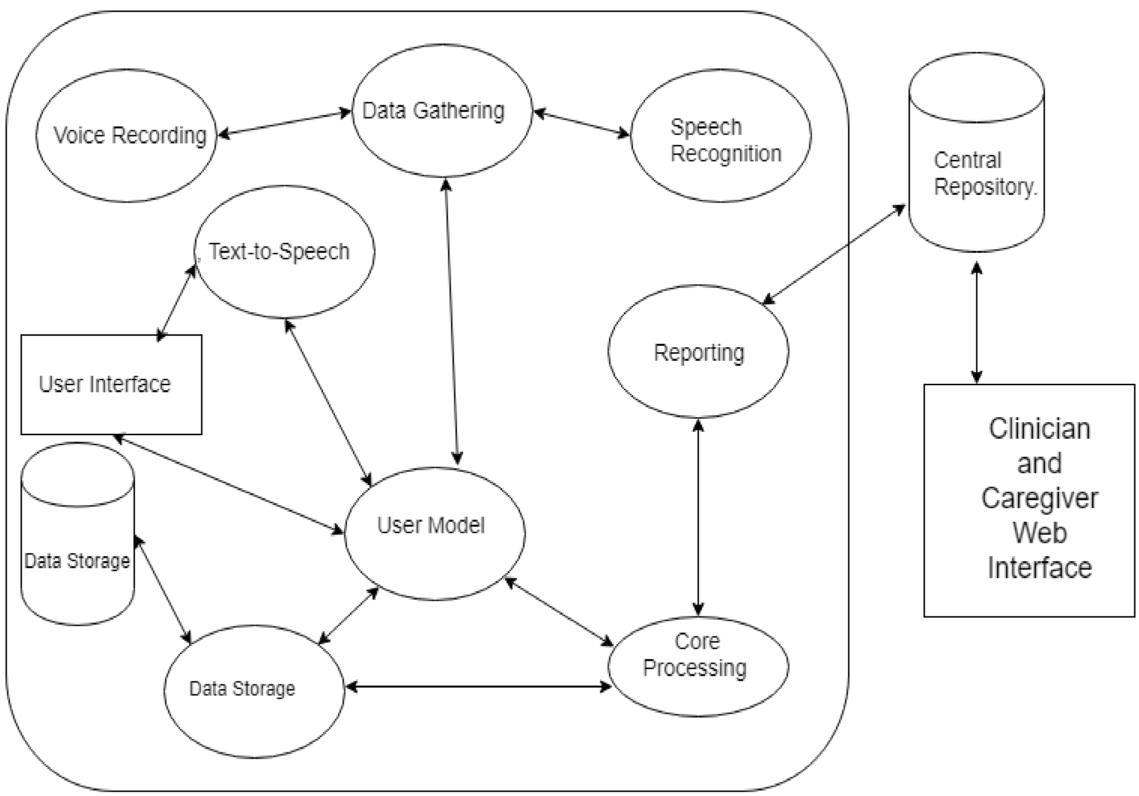

Fig. 3.1: System architecture of “iHeartU” application.

The reporting module will broadcast these subjective self-reports to a server at the hospital for viewing by healthcare practitioners and caregivers by online web-based

application. The practitioners and caregivers can look at these reports and provide their feedback which will be received back by the user through core processing module.

INTERFACE

The interaction metaphor of the user interface module for the "iHeartU" application features an interactive virtual assistant named Iris. Iris is an interactive virtual human (VH) or embodied conversational agent that resembles a human assistant in terms of appearance and behavior and is meant to provide natural social interaction with users of the system. Iris is designed to represent the system as a social interface and enable users to provide information to the system and receive feedback leveraging day-to-day social interaction as a metaphor for human-computer interaction. Iris is capable of engaging users in a face-to-face dialogue though speech recognition, text-to-speech and demonstrating emotional nonverbal reactions through various animations.

Iris is tailored to appear as a human to facilitate a sense of familiarity to the patient. Studies have shown that attractive agents are more influential as social models for college students compared to less attractive agents [9]. In addition, among attractive agents, young and cool agents were most influential [23]. Therefore, we designed Iris to be young, attractive and cool. We also provided Iris with the capability to change clothes so that every time users open the "iHeartU" application to interact with Iris, they will get the sense of a fresh look each time. To achieve this sense of freshness, we provide six pairs of clothes that Iris can randomly choose from before appearing in front of the users. We also randomly change the background for Iris for each session; this is expected to give the perception of

a pleasing environment and fresh look each time. Some of the visuals of the interface can be seen in (Figure 3.2).

Iris requests patients to give a report of their general progress, medications, activity, and other behavioral aspects via natural dialogue and then records the users' responses as audio files. These audio files will be periodically uploaded by the reporting module to the server so that the clinician can monitor the patient's progress as needed via a web-based interface. Iris uses text-to-speech for its speech audio output, with visemes extracted from the phonemes of a script for the conversational lip-sync interaction. The behaviors of Iris consist of pre-canned skeletal animations and facial expressions like smiling, pertaining to the content of the interaction that will be evoked based on a basic interaction defined in "iHeartU".

We designed "iHeartU" to be used by people of all ages. Many seniors have physical conditions or health issues that make hearing difficult or challenging. Taking this notion into consideration, we provide the option to adjust speech rate with which Iris would initiate personalized conversational interactions and to enable subtitles in the "iHeartU" settings. This can be seen in (Figure 3.3).

Fig. 3.2: “iHeartU” interface visuals.

Fig. 3.3: Iris personalized conversational interactions with subtitles enabled.

The personalized conversational interactions between Iris and the patient are designed to be motivational, constructive and provide guidance to the patient with constant input from the clinicians and caregivers in the loop. Patients have the facility at any time to convey messages and alerts to their clinicians and caregivers by reporting it to Iris. Patients are also able to receive messages from their care providers conveyed by Iris. For instance, the patient will be immediately alerted by Iris if the physician wants to see the patient. Users can interact with Iris via simple speech commands or via input buttons of pre-defined answers, in the event that speech recognition is in error due to a noisy environment.

The "iHeartU" application utilizes the innate speech recognition platform of the smartphone for recognition of keywords and phrases based on the content of the interaction. The expected outcome of this innovation is that the patient will find an endearing, engaging, socially motivating, rapport-forming VH assistant. This assistant is not only an intuitive, friendly and easy to use interface, but it is also a reliable virtual entity who performs timely functions of reporting patients' progress and physiological data to stakeholders, as well as conveying critical messages and information to the patient from providers.

CLINICIAN AND CAREGIVER INTERFACE

The "iHeartU" application periodically interfaces with a server application that is executed on the clinical side to report patient information (self-reports) to a backend database. The backend database is password protected so that only clinicians providing

care to the patient will be able to monitor their data and access the information of the patient concerned. Every clinician, caregiver or patient must have an account on the server to use the “iHeartU” application. The administrator can create a account for user as seen in (Figure 3.4).

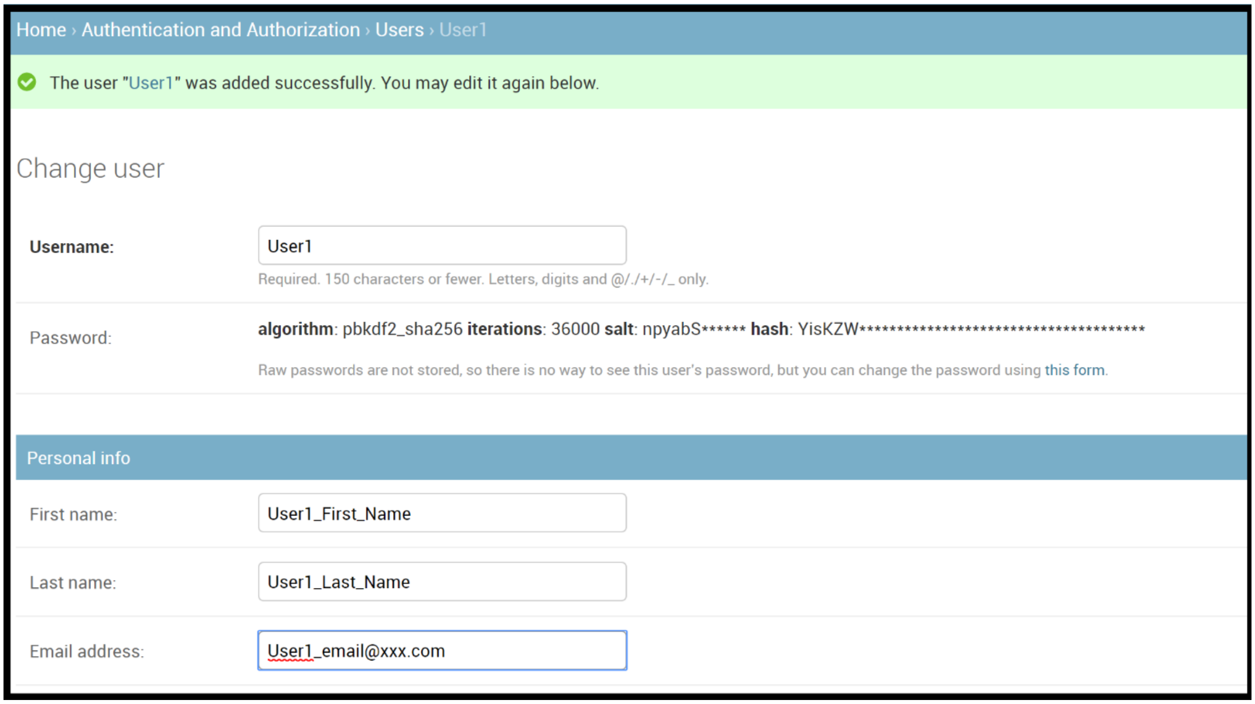

Fig. 3.4: “iHeartU” web interface to create a user account.

The administrator needs to assign the user to the respective group such as doctor, care provider or patient as seen in (Figure 3.5). Doctors and care providers have permissions to access the daily report of their patients. The patient will be assigned to the respective doctors and care providers who will be able to see their responses and daily self-report in their dash board.

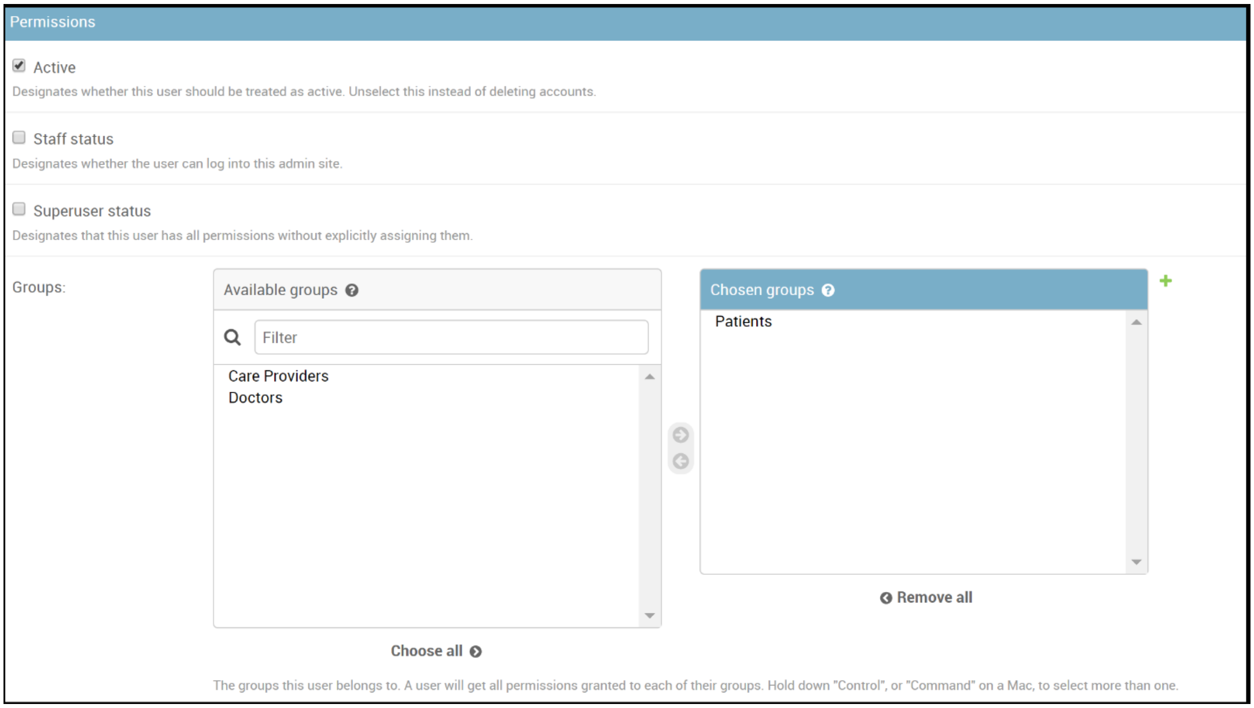

Fig. 3.5: “iHeartU” web interface to assign the user to the respective group such as doctor, care provider or patient.

The doctors can create a questionnaire for each patient requesting for subjective input regarding symptoms, sleep habits, patient activity, dietary intake and output, medication, orientation and general demeanor through this web interface as seen in (Figure 3.6). Doctors can also assign the type of questions to the questionnaire. There are four types of questions, namely Yes/No, open-ended, Yes/No (No follow up) and statement. If the question is of type Yes/No, then Iris will only expect a Yes or No response through speech. The doctor needs to assign a nested question for Yes/No answers. For Instance, if the first question of type Yes/No is “Have you had anything to eat in your lunch?”, doctors can assign another question for each possible answer. So, for the “Yes” response doctors can

assign an open-ended question, such as “What did you have in your lunch?”. For open-ended questions, Iris will provide a microphone and users can record their responses as an audio file. For a “No” response, doctors can assign a statement, which can be advice to the patient like “Please be sure to eat three times daily”. For statement type questions, Iris will not expect any responses from the patient. For Yes/No (No follow up) questions, Iris will only expect “Yes” and “No” responses and there will be no follow-up questions.

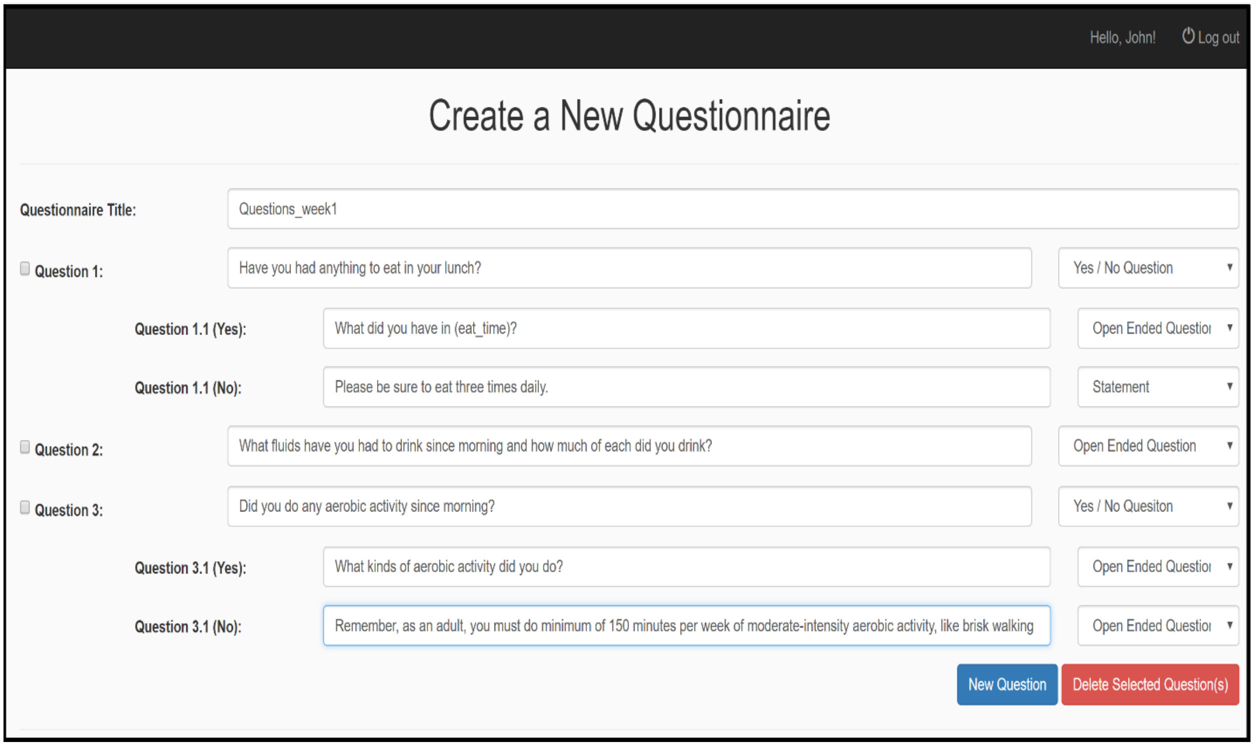

Fig. 3.6: “iHeartU” web interface to create a questionnaire for each patient.

Upon logging through user credentials in a web-based application, clinicians and caregivers will be able to access detailed logs of a patient’s weekly diary of progress and self-reports as seen in (Figure 3.7).

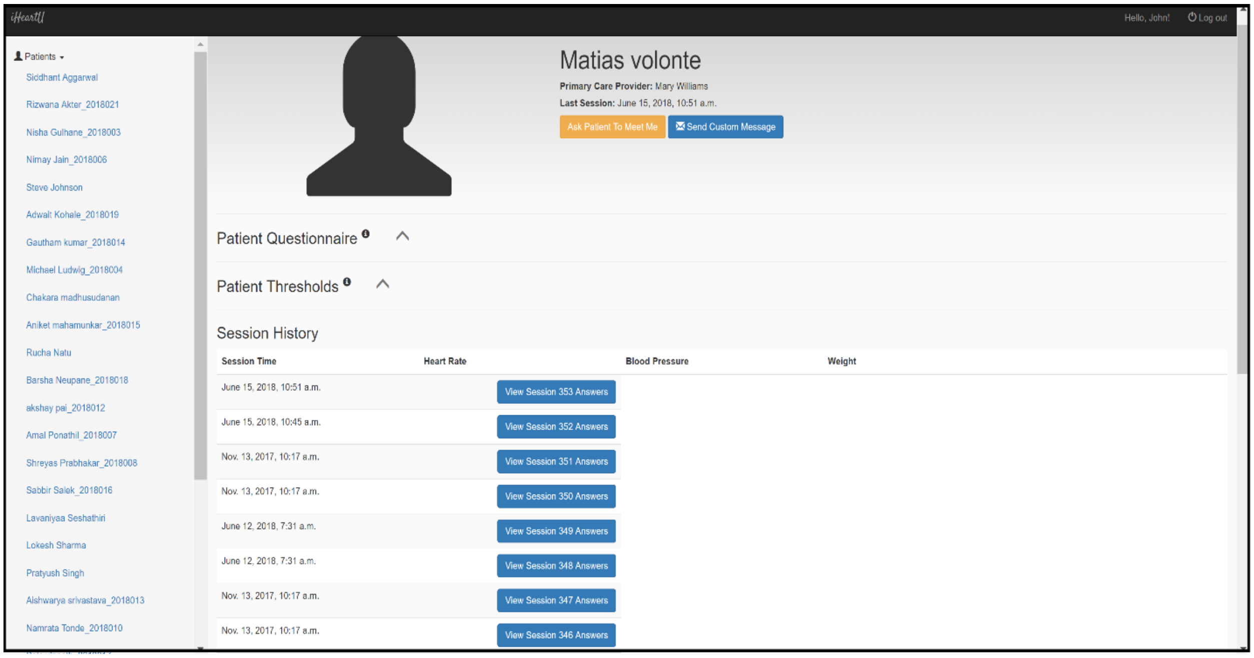

Fig. 3.7: "iHeartU" web interface of detailed logs of a patient's weekly diary of progress and self-reports.

The web-based application also has patient messages and self-reports as links to playable audio files for the clinicians and caregivers to examine as seen in (Figure 3.8).

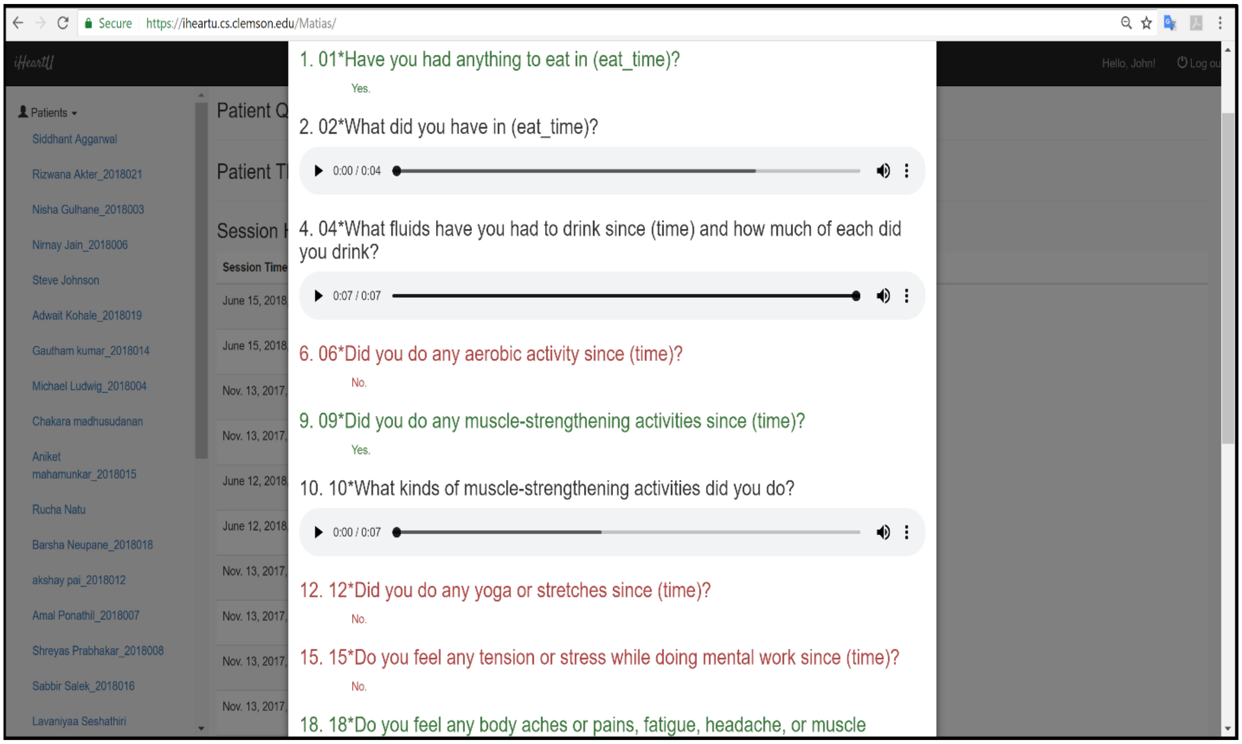

Fig. 3.8: "iHeartU" Web interface of patient messages and self-reports as links to playable audio files for the clinicians and caregivers to examine.

The clinician can write a message for the patient that will be interpreted by Iris and Iris will then proactively alert the patient. These alerts can include an immediate visit to the clinician, a change in medication, a change in activity or movement, etc. as seen in (Figure 3.9).

The doctors can also assign the risk level of the patients for their objective responses, such as blood pressure, heart rate, weight or stress level (as seen in Figure 3.10). If the patient objective responses crosses the threshold, the doctors will be notified on the patient's dashboard by marking that session in red (as seen in Figure 3.11).

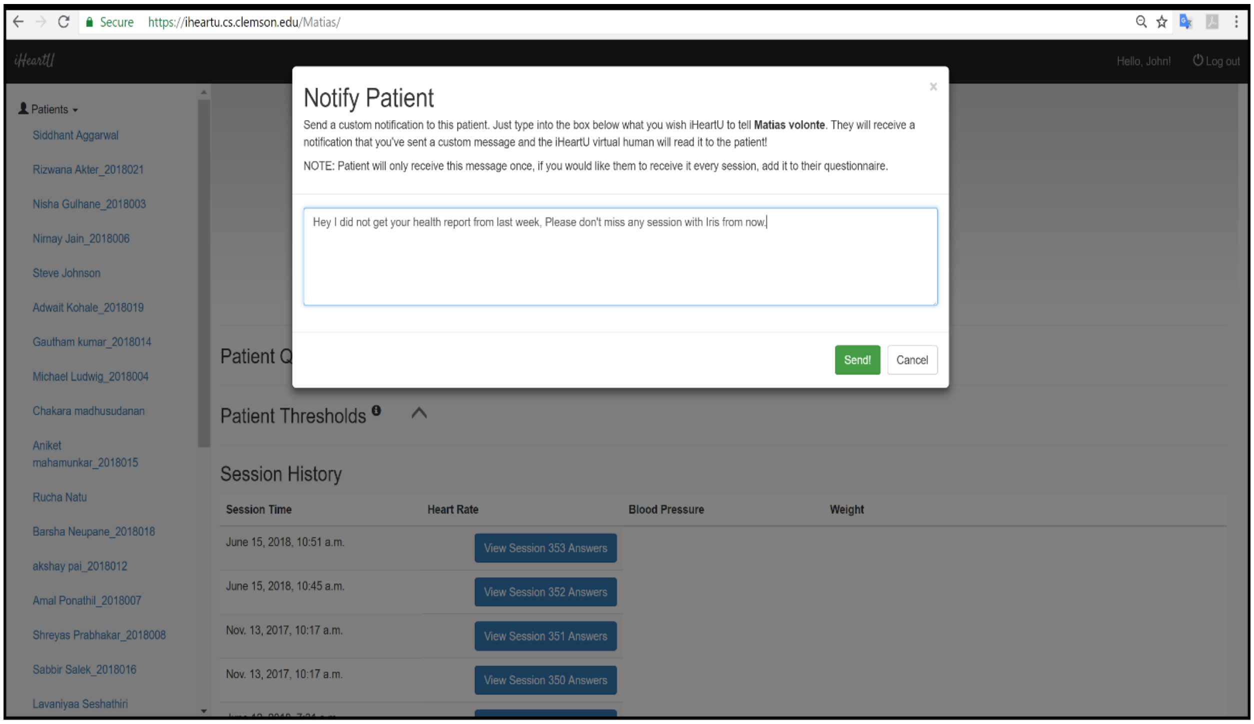

Fig. 3.9: “iHeartU” web interface for clinician to write a message for the patient that will be interpreted by Iris and Iris will then proactively alert the patient.

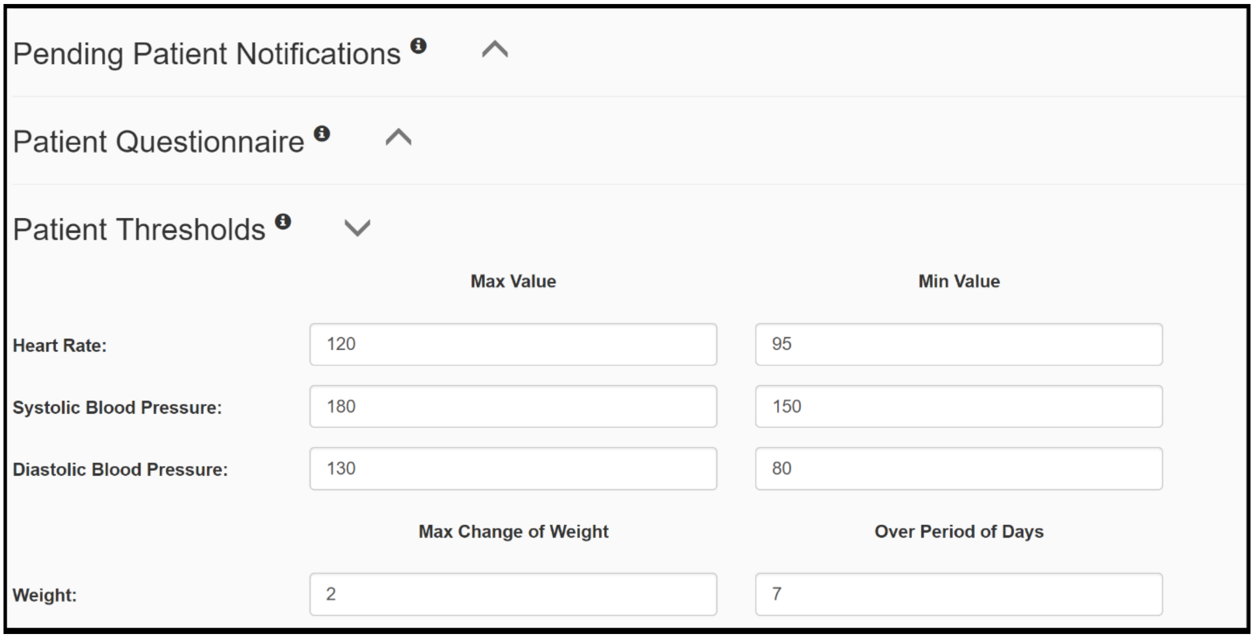

Fig. 3.10: "iHeartU" web interface to assign the risk level.

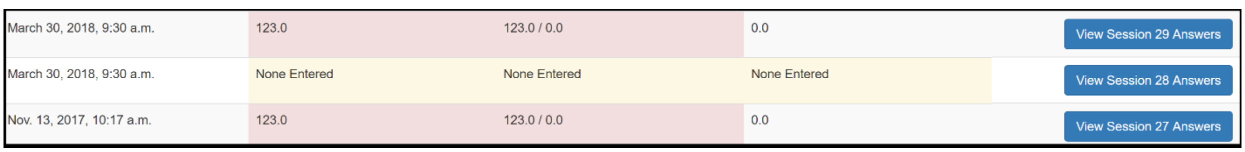

Fig. 3.11: "iHeartU" web interface to notify doctors about patient crossing the threshold for objective response.

FRAMEWORK IMPLEMENTATION

We implemented the "iHeartU" application for Android platform on Unity3D, which is a widely used gaming engine. "iHeartU" utilizes the innate speech recognition platform of Android for recognition of key words and phrases based on the content of the interaction, as well as the dictation of user's speech-to-text for parsing relevant information

from their speech input. Our app also utilizes Android multimedia framework for capturing audio responses from the users in case of open-ended responses.

We incorporated a 3D character from Morph 3D for the virtual human interface condition. This 3D character is highly customizable as it comes with many pre-installed blend shapes and is compatible with many online assets such as RT-voice and Salsa. We used RT-voice for the text-to-speech audio conversion, and we complemented this system with Salsa for activating the proper blendshape of character for creating the speech illusion.

The animations of the Virtual Human (Iris) where mostly keyframed based. These were created by animating a custom rig created for this project. These animations were created in Maya software and then exported to Unity3D. Finally, in this game engine, the animations were triggered based on the content of interaction with the user. We modeled different conversational scenarios that were defined in the “iHeartU” application. For example, one conversation scenario includes the following: when the user opens or close the “iHeartU” application, Iris would greet the user by saying hello with a hand waving gesture (see Figure 3.2). Another example of a conversation scenario occurs in the first three initial sessions; Iris will explain to the user about how to use the “iHeartU” application. When Iris explains to the user how to record the responses, she points her hand with a taping gesture towards the microphone icon and tells the user that they need to tap the microphone (see Figure 3.12).

Fig. 3.12: “iHeartU” interface with Iris explaining how to record responses.

When Iris asks the question, she shows a inquiring gesture (see Figure 3.13), and when she is done asking a question she goes back to her normal form, implying that now she is expecting a response. When there is an open-ended question and users needs to record their responses, Iris will look and point towards the microphone (see Figure 3.14). The other conversation scenario consists of Iris not understanding the users’ speech responses. In this scenario, Iris will show a confused gesture and will ask the user to repeat themselves (see Figure 3.15).

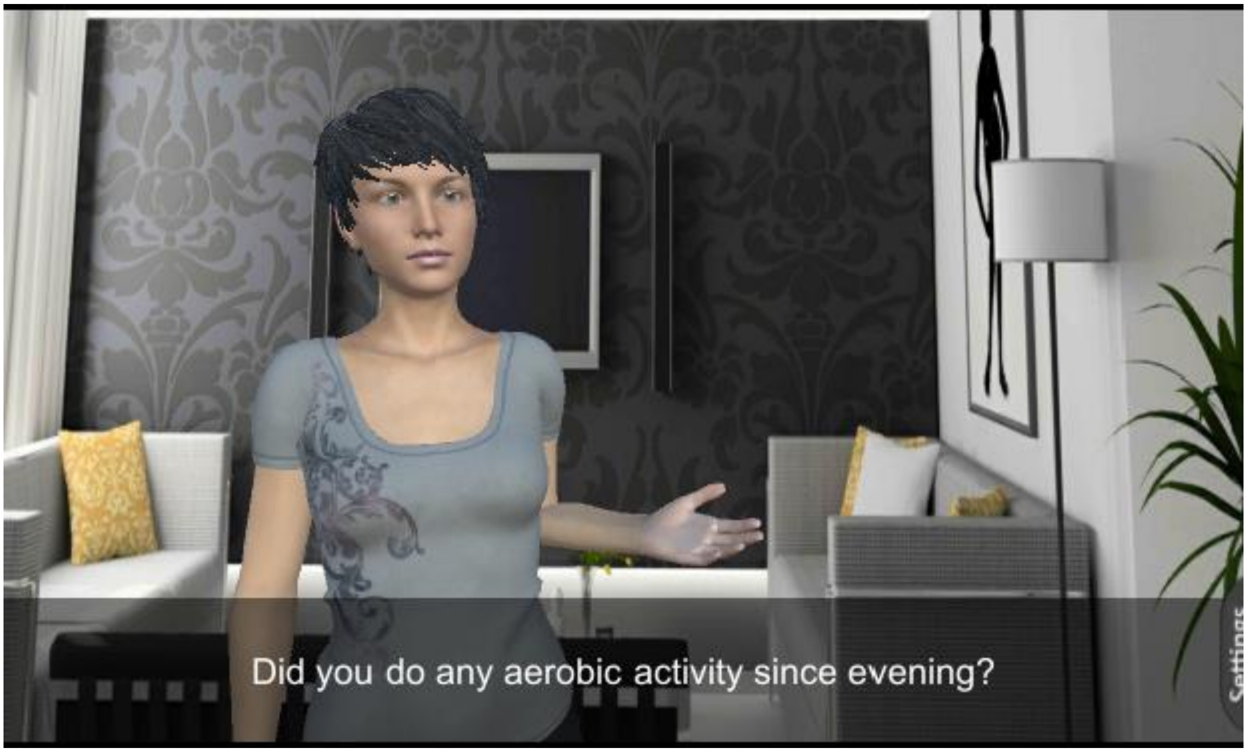

Fig. 3.13: “iHeartU” interface with Iris asking a question.

Fig. 3.14: “iHeartU” Interface with Iris asking to record response.

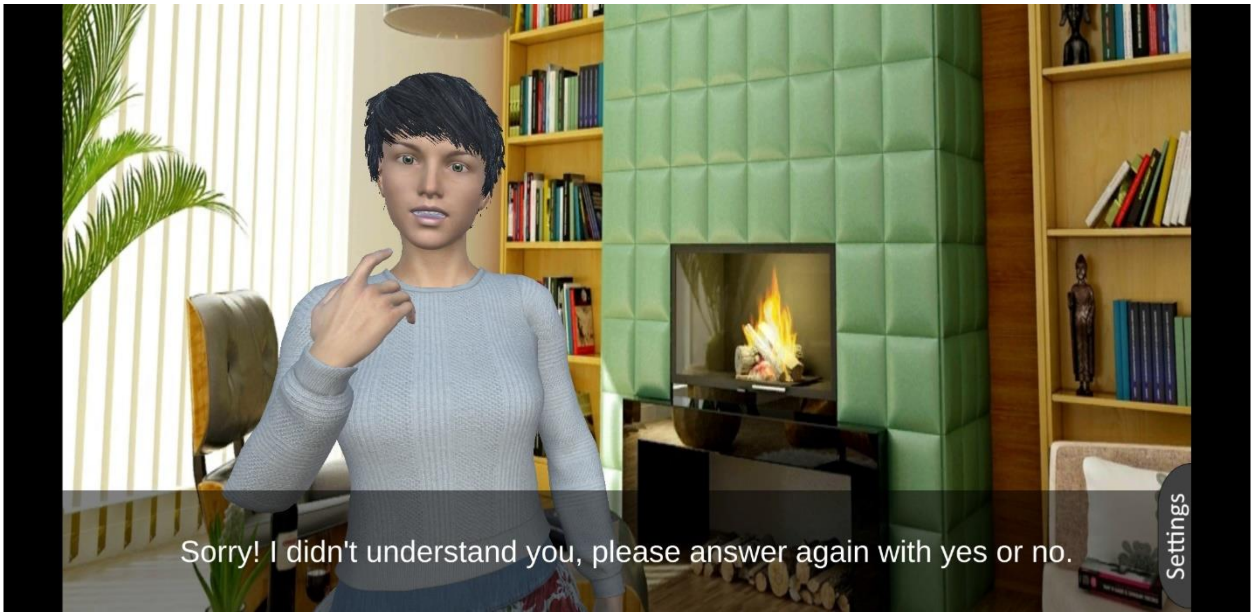

Fig. 3.15: “iHeartU” interface with Iris confused after not understanding the speech response.

We imbed an SQLlite database system into the “iHeartU” application which is used to store patients’ preferences, logging of their inputs and progress. These useful data are periodically broadcasted to the central repository on the server.

The “iHeartU” online web-server relies on Django, which is written in Python and designed specifically for web development. Django design dictates websites as individual “apps” where each app serves a specific purpose for operations of the website. “iHeartU” is divided into two such apps: Questionnaires and Patients. Questionnaires handles building and modifying of Questionnaires in the system while Patients handles building and modifying patient data in the system. We created a database (central repository) on the “iHeartU” server. In addition to a number of tables built by Django for our server, a small

number of tables were designed specifically for “iHeartU”. These tables were built across two apps: Patients and Questionnaires. For Patients application we created tables: “UserProfile”, which extends Django’s prebuilt user account table to add more variables necessary for “iHeartU”; “Session”, which contains “iHeartU” session headers and a list of all sessions completed by users; “Responses”, which contains a list of responses to all questions answered by users; and “Notifications”, which contains a list of active notifications waiting to be received by patients. For “Questionnaires” application, we created two tables: “Questionnaire”, which contains questionnaire headers and “Question”, which contains all questions and questionnaires they relate to. The Django server code was hosted on Apache2 which is a HTTP server software that hosts the server code in production environments. The Postgresql, which is an opensource database system, is used to serve as a central repository for the “iHeartU” application.

To allow the “iHeartU” server to communicate with the “iHeartU” Android smartphone app, we used REST API (Representational State Transfer). REST is an architectural style that defines a set of constraints and properties based on HTTP. REST-compliant web services allow the requesting systems to access and manipulate textual representations of web resources by using a uniform and predefined set of stateless operations [51].

REST API is the method used to allow smartphone applications to communicate with the webserver. Essentially, REST API designates certain URLs on the server’s address space to act as the access point for uploading and downloading data. These URLs return JSON documents instead of standard HTML. For applications “Patient” and

"Questionnaires" on the server we have few classes; these class declarations describe how to handle all of the REST API points of the server. Moreover, these REST API access points in "iHeartU" have been designed so that they are only accessible by authorized users and, even then, the information returned is restricted based on the user accessing the access point. Authorization is achieved by placing a unique authorization token for each user in the header of the HTTPS requests to these access points. An authorization token for a user is obtained using on the following API access points.

Below is a list of all the API commands available through REST for GET and POST method. All REST API URLs are part of the "/apis/" section of the website.

1) /apis/patient/sessions/
   a) GET: returns list of all sessions completed by this user.
   b) POST: creates a new session in the database with ID 1 greater than the most recently created session.
2) /apis/patient/sessions/{ID_number}/
   a) GET: returns list of this user's responses to the given session ID.
   b) POST: adds the posted question response to this session ID.
3) /apis/patient/sessions/{ID_number}/vitals/
   a) GET: returns list of this user's vitals for the given session ID.
   b) POST: adds the posted vitals values to this session ID.
4) /apis/patient/sessions/{ID_number}/end_session/
   a) GET: N/A.
   b) POST: sets the end time to now for the given session ID.
5) /apis/patient/sessions/{ID_number}/{Question_number}
   a) GET: N/A.
   b) POST: uploads a recorded response (as a .wav file) to be associated with the given question number on the given session ID.
6) /apis/patient/notifications/
   a) GET: retrieves all the pending notifications in the system for the user and returns them.
   b) POST: N/A.
7) /apis/patient/notifications/confirm_meetings/
   a) GET: flags all meeting request notifications for this user in the database as confirmed.
   b) POST: N/A.

8) /apis/patient/notifications/confirm_messages/
    a) Get: flags all custom message notifications for this user in the database as confirmed.
    b) POST: N/A.
9) /apis/get_auth_token/
    a) GET: N/A.
    b) POST: returns an authorization token for a user if supplied with valid login information
10) /apis/user/
    a) GET: returns the currently logged in user’s name.
    b) POST: N/A
11) /apis/questionnaire/
    a) GET: returns the list of all questions on the users current questionnaire (questions Iris needs to ask).
    b) POST: N/A.
12) /apis/questionnaire/{title}
    a) GET: returns list of all questionnaires owned by a doctor (if current user is a doctor, this API access point is only useful for doctors).
    b) POST: N/A.

```
                                  +---------+
                                  |  USER   |
                                  +---------+
                                       ^
+--------------------------+           |       +-----------------+      +-------------------
+
| USER PROFILE             |           |       | SESSION         |      | RESPONSES
|
+--------------------------+           |       +-----------------+      +-------------------
+
| user                     |----------+-------| user            |<-----| session
|
| id_number                |           |       | session_id      |      | question_number
|
| middle_initial           |           |       | start_time      |      | question
|
| gender                   |           |       | end_time        |      | isBoolResponse
|
| phone_number             |           |       | questionnaire   |      | boolResponse
|
| doctor                   |           |       +-----------------+      | recordedResponse
|
| care_provider            |           |                       ^        +-------------------
+
| questionnaire            |           |       +------------+   |
| profile_picture          |           |       | VITALS     |   |
| min_heart_rate           |           |       +------------+   |
| max_heart_rate           |           +-------| user       |   |
| min_systolic             |           |       | time       |   |
| max_systolic             |           |       | systolic   |   |
| min_diastolic            |           |       | diastolic  |   |
| max_diastolic            |           |       | heartrate  |   |
| weight_change_over_days  |           |       | weight     |   |
| max_weight_change        |           |       | session    |--+
+--------------------------+           |       +------------+
                                       |
+------------------+                   |
| NOTIFICATION     |                   |
+------------------+                   |
| title            |                   |
| message          |                   |
| meetingRequest   |                   |
| patient          |-------------------+
| received         |                   |
| confirmed        |                   |       BOLD = Patients model
+------------------+                   |       ITALICS = Questionnaire model
                                       |
+-----------------+                    |
| QUESTIONNAIRE   |                    |
+-----------------+                    |
| title           |                    |
| owner           |--------------------+
+-----------------+<-+
                     |
+-----------------+  |
| QUESTION        |  |
+-----------------+  |
| qid             |  |
| question        |  |
| trueid          |  |
| falseid         |  |
| Questionnaire   |--+
+-----------------+
```

Fig. 3.16 The general database design of how the tables relate on the “iHeartU” server.

CHAPTER FOUR

EVALUATION OF THE SYSTEM

Hypothesis and Research Questions

The goal of this study is to investigate the effect of an agent-based interface over a typical interface in a mobile health application on the users. Based on our research literature, we expect:

- Hypothesis 1: Virtual Human condition users will exhibit higher scores on the measure regarding the usage of the “iHeartU” app. These measures are: total time of usage, number of sessions and number of questions answered.
- Hypothesis 2: Can Virtual Human cause behavioral change with the users on mobile platform.
- Hypothesis 3: Can Virtual Humans motivate the users to follow healthy lifestyles on a mobile platform.

Study Design

To empirically examine each of these questions. We had two between-subjects conditions: a textual graphical with audio and an intelligent Virtual Human interface. Both the conditions were similar in terms of features, such as speech recognition, audio recording and text-to-speech. In the textual condition we removed the virtual human with the text. All the questions and input method were similar in both conditions. We designed a questionnaire for physical, eating and stress behavior on the server that are asked to the participants by Iris. These questions can be found in (Appendix A).

We recruited both male and female participants, who are over the ages of 18 and have an Android smartphone. We ran a total of 17 participants (8 in a textual graphical condition, 9 in Virtual Human interface) who were recruited from Clemson University. We had a near equal distribution of gender in both conditions that included 12 males and 5 females.

Methodology

Participants first listened to a brief explanation regarding the design and objectives of the “iHeartU” application. They were told to use the application for three weeks, a total of 21 days, and they were offered a $25 gift card upon completion of the experiment. They were encouraged to use the app as many times as they wanted, but use at least once a day was required. They were also required to meet weekly with us to hand over the log file and response files, which were generated in their phone. After consent was obtained, we asked the participants to fill out the following surveys: demographic, IPIP, big five factor, technology acceptance, exercise activity, perceived stress scale, eating behavior and PHQ9. Once they filled the survey, we created their account on the “iHeartU” server and then installed the app on their phone. We then briefed them on how to use the app and then let them use it once. We then pulled the log files from their phones to make sure everything was working perfectly as expected and then we thanked them for their time.

After a week, we met with them and pulled all the log files and response files from their phones. During the same meeting, we gave them following surveys: PHQ-Questions,

perceived stress scale, eating disorder scale, physical activity scale and qualitative survey. We then thanked them for their time.

After three weeks, we met with them and pulled all the log files and audio response files from their phones. We then uninstalled the app from the phone and ask them to fill out the following surveys: exercise activity, perceived stress, PHQ9, Virtual Human social presence-copresence and eating behavior. We then thanked them for their time.

CHAPTER FIVE

RESULTS

Measures

To establish the degree of incidence the different conditions of the application had on the users, we analyzed objective and subjective measures.

The objective data was obtained based on the interaction with “iHeartU” by the participant. When the user accessed the app, we collected the number of questions answered after each week, the number of daily sessions per day they accessed the app and the total time of usage. Also, during interaction with the app, users input their subjective degree of physical and mental stress. This process was applied for both conditions, the Virtual Human and the non-Virtual Human groups.

Other subjective measures were collected when the experiment started, such as the perceived stress scale and physical activity questionnaires.

In an attempt to better interpret the quantitative items, we used a number of open-ended discussion questions as a qualitative measure. These questions were used to assess participants’ overall experience with iHeartU. Two examples of these questions are: “How would you describe Iris’s personality?” and “What is your most favorite feature that Iris/this app has?”

Finally, we collected data in a pre-questionnaire when the experiment initially started as well as in a post questionnaire session a week after the experiment started and later after three weeks experiment ended.

Objective result

Phone usage

We used the *Kruskal-Wallis Test* for analyzing these variables between conditions on the pre-questionnaire data and in-between conditions in the post. This is a rank-based nonparametric test that can be used to determine if there are statistically significant differences between two or more groups of an independent variable on a continuous or ordinal dependent variable.

It is considered the nonparametric alternative to the one-way ANOVA, and an extension of the *Mann-Whitney* test to allow the comparison of more than two independent groups.

We collected the users' interaction with the application for a period of twenty-one days after the initial visit, we averaged this data on each participant per week. We did this process for all the variables, namely Number of Questions, Number of Sessions, Total Time of Usage, Level of Mental Stress and Level of Physical Stress. Figure 5.1 shows DATA_TABLE for the study samples descriptive.

The variables in the DATA_TABLE are: *sample size* represent total number of participants in a given condition, *total_session* represent total number of sessions, *total_time* represent total duration of all sessions, *number_of_questions* represent total number of questions answered for all sessions, *physical_stress* represent reported physical stress for all sessions, *mental_stress* represent reported mental stress for all sessions. The suffix 1, 2, 3 are used to describe week one, week two and week three respectively.

NVH		N	Mean	Std. Deviation
	Sample Size	8		
	total_session.1		5.50	2.070
	total_time.1		0:05:49.28	0:01:31.32638
	number_of_questions.1		11.3495	0.38240
	physical_stress.1		1.8960	1.03614
	mental_stress.1		2.0898	1.15064
	total_session.2		4.38	2.615
	total_time.2		0:05:09.08	0:01:06.88824
	number_of_questions.2		11.4582	0.44291
	physical_stress.2		1.8021	0.94064
	mental_stress.2		1.7188	0.99497
	total_session.3		4.25	3.059
	total_time.3		0:04:57.05	0:01:07.67490
	number_of_questions.3		11.4394	0.71710
	physical_stress.3		1.7875	1.23223
	mental_stress.3		1.6250	0.88641
	VH	N	Mean	Std. Deviation
	Sample Size	9		
	total_session.1		5.89	3.371
	total_time.1		0:05:03.27	0:00:22.15976
	number_of_questions.1		11.4830	0.36311
	physical_stress.1		2.2152	1.19288
	mental_stress.1		2.6376	1.81570
	total_session.2		5.78	2.587
	total_time.2		0:04:45.65	0:00:32.97767
	number_of_questions.2		11.9571	0.77954
	physical_stress.2		2.2032	0.73983
	mental_stress.2		2.4746	1.33033
	total_session.3		6.44	2.698
	total_time.3		0:05:04.53	0:00:46.52625
	number_of_questions.3		11.9053	1.07934
	physical_stress.3		2.7556	1.76981
	mental_stress.3		3.2864	2.32560

Fig. 5.1 DATA_TABLE shows the descriptive statistics of the *Phone Usage* variables.

In order to measure if the engagement level of participants in Virtual Human interface condition differ with the textual audio interface condition and to examine the reported mental stress and physical stress difference between the two conditions, we conducted a *Kruskal-Wallis Test* on the mean of variables: Number of Questions, Number of Sessions, total Time of Usage, Level of Mental Stress and Level of Physical Stress. The conducted test is done for each of these variables between each week for both the conditions.

The *Kruskal-Wallis Test* did not reveal any significant difference between groups in any of the analyzed variables. However, significant increase was found on the Virtual Human (VH) condition in the *number_of_questions* answered in the first week (M=11.48, SD=0.36) and the second week (M=11.95, SD=0.77) of phone usage Z= -1.95, p=.05. The mean graph of number of questions answered by participants in VH condition for each week can be seen in Figure 5.2. Moreover, in the Non-Virtual Human (NVH) condition we found a significant decrease in the total Number of Sessions between week one (M=5.5, SD=2) and week two (M=4.38, SD=2.61), Z=-1.98, p=0.047. The mean graph of total number of sessions completed by participants in NVH condition for each week can be seen in Figure 5.3.

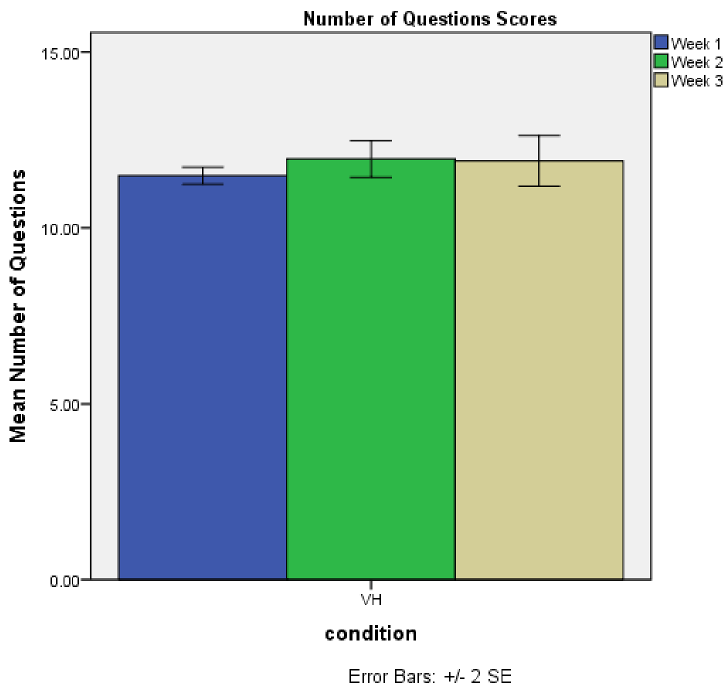

Fig. 5.2 The mean graph of number of questions answered by participants in VH condition for each week.

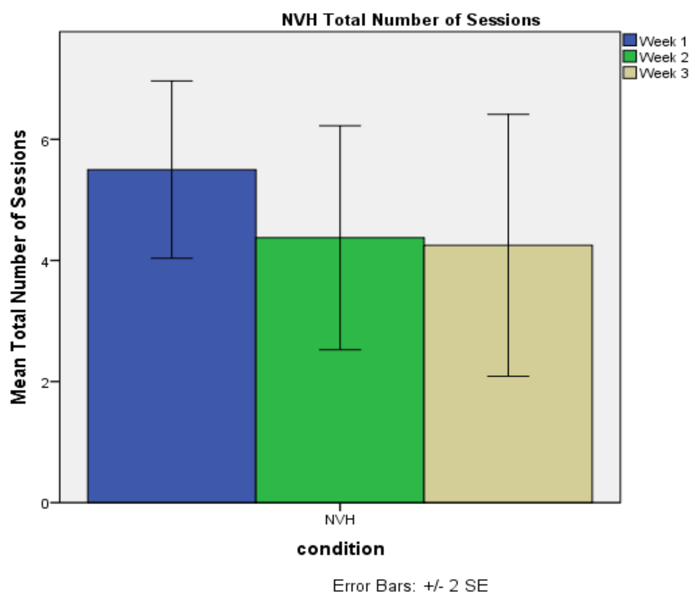

Fig. 5.3 The mean graph of total number of sessions completed by participants in NVH condition for each week.

Quantitative analysis:

We did quantitative analyses of the total session completed variable by participants in both condition, Virtual Human VH and non-Virtual Human (NVH). We found that mean of total number of sessions completed per week by participants in NVH condition gradually decrease per week while for the participants in the VH condition, it is nearly constant between the first two weeks and increases in the third week. The mean graph of total number of sessions completed by participants in both condition for each week can be seen in Figure 5.4.

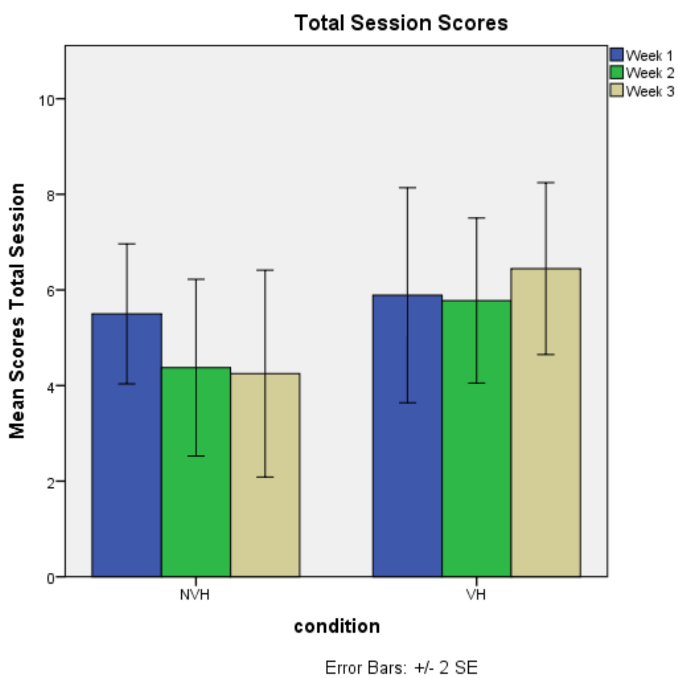

Fig. 5.4 The mean graph of total number of sessions completed by participants in both condition for three weeks.

Furthermore, we did quantitative analyses of total time usage of the app by participants in both condition, VH and NVH. We found that mean of total time usage of

the app by participants in NVH condition gradually decrease per week while for the participants in the VH condition, it is nearly constant over three weeks. The mean graph of total time usage of the app by participants in both condition for each week can be seen in Figure 5.5. The quantitative analyses of mean of number of questions answered in both condition is found to be nearly constant in both the condition. The mean graph of total number of questions answered by participants in both condition for each week can be seen in Figure 5.6.

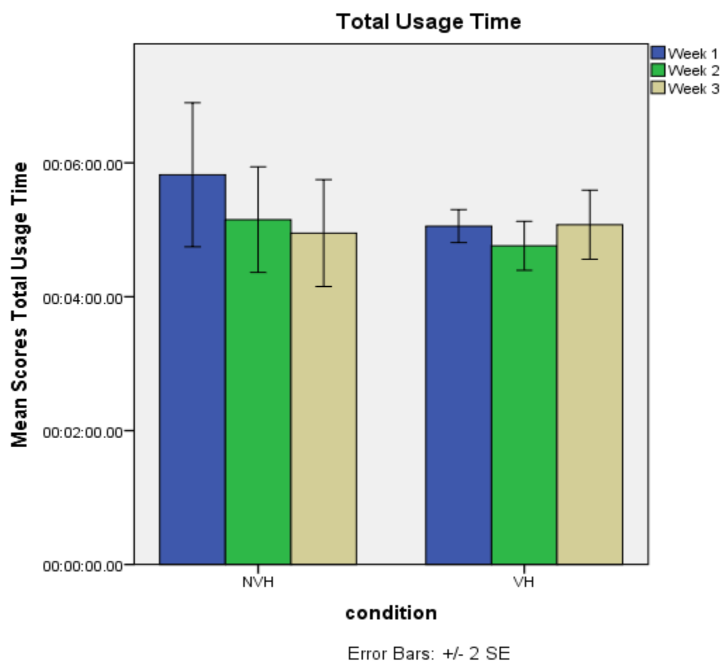

Fig. 5.5 The mean graph of total time usage of the app by participants in both condition for three weeks.

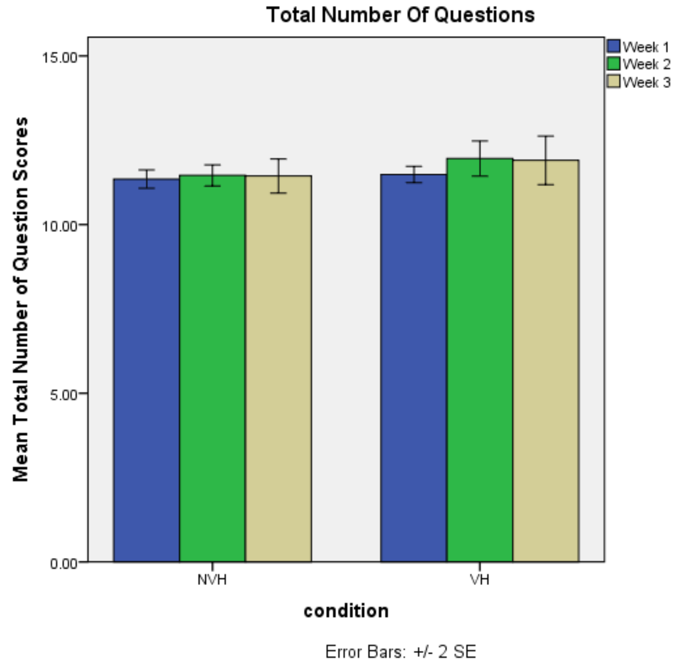

Fig. 5.6 The mean graph of total number of questions answered by participants in both condition for three weeks.

Subjective surveys

To assess if there was any significant incidence on the users' behavior after the three weeks of interaction with "iHeartU", we collected and analyzed the users' perceived stress level on a pre and post questionnaire.

The analysis procedure consisted in a Mann-Whitney's U test to evaluate the difference in the responses between groups on the pre and post survey. We adopted this test because it is used to compare differences between two independent groups when the dependent variable is either ordinal or continuous, but not normally distributed.

Furthermore, for comparing the users' scores in each group in the pre and post questionnaire, we utilized the Wilcoxon signed-rank test method. This is a nonparametric

test equivalent to the dependent t-test. As the Wilcoxon signed-rank test does not assume normality in the data, it can be used when this assumption has been violated and the use of the dependent t-test is inappropriate.

<u>Stress Survey</u>

We implemented the Perceived Stress Scale questionnaire since it is widely used in the psychology field. It has an Items that were designed to tap how unpredictable, uncontrollable, and overloaded respondents find their lives. The scale also includes several direct queries about current levels of experienced stress. We decided to implement this scale since our study is a longitudinal 21 day and this survey asks the participants about their feelings and thoughts during the last month. The questions in this scale ask about your feelings and thoughts during the last month. In each case, it asks how often you felt or thought a certain way. For example, “In the last month, how often have you been upset because of something that happened unexpectedly?” another example would be “In the last month, how often have you felt that you were unable to control the important things in your life?” and participants have options to choose from: “Never”, “Almost Never”, “Sometimes”, “Fairly Often”, “Very Often”. We transformed these responses in numerals 0, 1, 2, 3, 4 respectively and conducted Wilcoxon signed-rank test and Mann-Whitney’s U test.

The Mann-Whitney’s U test did not reveal any significant effect between groups on the pre and post questionnaire. However, Wilcoxon signed-rank test method revealed a significant difference on the users in the NVH condition. Users in this condition scored a higher stress level in the baseline pre-survey (M=19.1, SD=3.5) than in the week one

intermediate survey (M=11.8, SD=3.5), p 0.018. Furthermore, users scored significantly lower in the third week (M=14.13, SD=6.73), p=0.027 over the baseline (M=19.1, SD=3.5).

Second, Wilcoxon signed-rank test method also revealed a significant difference on the users in the VH condition. Users in this condition scored a higher stress level in the baseline pre-survey (M=18.5, SD=2.9) than in the week one intermediate survey (M=12.11, SD=6.051), p 0.012. Furthermore, users scored significantly higher in the third week (M=13, SD=7.09), p=0.008 over the baseline (M=18.5, SD=2.9) (see Figure 5.7, 5.8).

Condition		N	Mean	Std. Deviation
NVH		8		
	Baseline		19.13	3.523
	Intermediate		11.88	3.523
	Final		14.13	6.73
VH		9		
	Baseline		18.56	2.920
	Intermediate		12.11	6.051
	Final		13	7.09

Fig 5.7: Result statistics of pre and post stress survey.

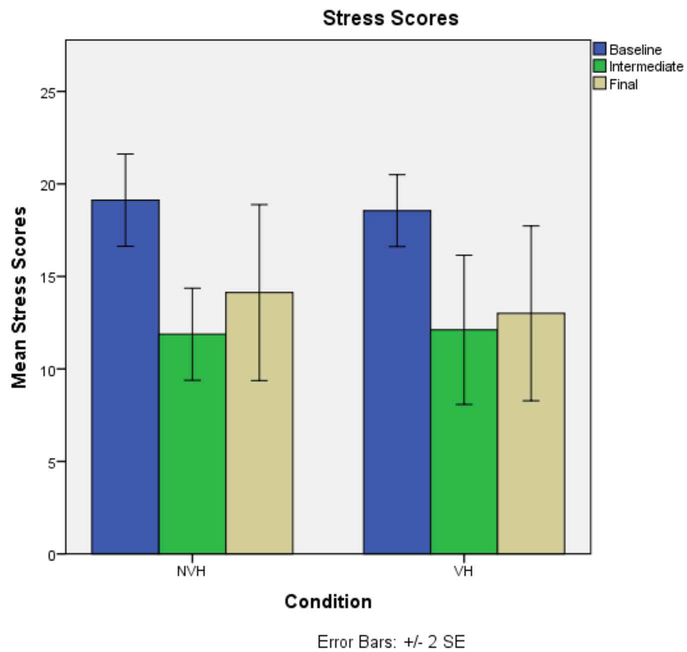

Fig 5.8: Mean graph of stress scores of NVH and VH condition for baseline, intermediate and post survey.

Physical activity survey

The International Physical Activity Questionnaires (IPAQ) comprises a set of four questionnaires that ask the user their physical activity for a period of one week in hours or minutes. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health-related physical activity. The survey has questions like: "At work I sit?", "At work, I walk?" and participants have options to choose from: never, seldom, sometimes, often, and always. Another example of a question would be: "In comparison with others of my own age I think my physical activity during leisure time is" and participants have options to choose from: "much more", "more",

“the same”, “less”, “much less”. We transformed these responses in numerals 4, 3, 2, 1, 0 respectively and conducted Wilcoxon signed-rank test and Mann-Whitney’s U test.

The Wilcoxon signed-rank test did not reveal any significant effect between groups on the pre and post questionnaire. However, Mann-Whitney’s U test method revealed a significant difference between VH and NVH condition. Users in VH condition scored a higher physical activity level in the baseline pre-survey (M=1.78, SD=0.44) than in the baseline for NVH (M=1.13, SD=0.64), p 0.03. We did not find any significant difference over the three weeks of usage on each condition (see Figure 5.9).

Condition	N	Mean	Std. Deviation
NVH	8		
Baseline		1.13	.641
Intermediate		1.25	.707
Final		1.63	.744
Condition	N	Mean	Std. Deviation
VH	9		
Baseline		1.78	.441
Week 1		1.78	.667
Week 2		1.44	.882

Fig 5.9: Result statistics of pre and post physical activity survey.

Co- Presence Survey

We incorporated the *"Internal Consistency and Reliability of the Networked Minds Measure of Social Presence*" [53] to measure the social presence effect on the users' of the Virtual Human Condition. This validated questionnaire of Social Presence is defined as the "*the degree of initial awareness, allocated attention, the capacity for both content and affective comprehension, and the capacity for both affective and behavioral interdependence with said entity*." In this experiment we used a 5 Point Likert scale for the different dimensions of this survey, namely: co-presence, attentional allocation, perceived message understanding, perceive affective understanding, perceived emotional interdependence and perceived behavioral interdependence.

In our survey: Co-presence is the extent to which participant believes they are with Iris, attentional allocation is the extent to which user was attentive to Iris and found Iris attentive to them, perceived message understanding is the extent to which user and Iris were able to understand each other, perceived affective understanding is the extent to which user and Iris were able to understand emotional and attitudinal states of each other, perceived affective interdependence is the extent to which the user and Iris emotional and attitudinal state affects are affected by each other. The questionnaire for each of these dimensions can be seen in Appendix E. The users' scores on each of the specified dimension can be seen in Figure 5.10.

Variable	Score
Attentional Allocation	2.98
Perceived Message Understanding	3.30
Perceived Affective Understanding	3.09
Perceived Emotional Interdependence	2.70
Perceived Behavioral Interdependence	2.96

Fig 5.10: The users' scores on each of the specified dimension on Co- Presence Survey.

Qualitative Results

To assess the qualitative differences between the Virtual Human and non-Virtual Human conditions at the end of first week, we asked participants to report on their overall impressions of interacting with Iris. In response to the question, "How would you describe Iris's personality?", participants in the virtual human condition mentioned for Iris, "She is very nice and understanding", "She is sweet and friendly", "Caring", "It looks like a real person, with all the emotions perfectly matched.", "She was nice to speak with and had a human feel to talk with and it was nice to talk to her". Whereas, participants in the non-virtual human condition responded "She is a bit slow while talking.", "Clearly audible, understand human language very well", "Robotic", "Motivating", "Caring about the user". There were eight participants in the non-Virtual Human condition; out of these, three participants found Iris to be robotic, while in a Virtual Human condition, three out of nine said that they found Iris friendly. Other participants also gave similar responses.

In response to the question, “What is your most favorite feature that Iris/this app has?”, participants in both conditions gave similar responses: “She cares so much about my health and responds in a clear way how to take care of my diet”, “Timely reminders/notifications during the day”, “iHeartU sends notifications every day which reminds me to take care of both physical and mental fitness also It gives advice about each and every activity.”, “This app motivated me to exercise and was easy to use.”, “I liked the design of the app. The fact that it asks each time to eat healthy foods or do aerobic activities is helpful because, after the first several times, it actually works. I think of managing time for doing those things.”, “It keeps a track of our meals and any problems that we might be facing.”. Besides one empty response, all the responses were positive, indicating that, overall, users liked the “iHeartU” design.

In response to the question, “What aspects of this app did you not like so much?” participants in both condition said, “Repetitive questions and responses”; the non-Virtual Human app users also said few things different, such as “Sometimes you have to be a little loud, so in public it might get uncomfortable.”, “Amount of time for the app to record my one-word responses”, “Same questions over and over again. The tone of voice sounded very machine-like. Repetitive responses”, “I wish it had buttons to type answers, along with voiceover by Iris, this could be helpful in the times I didn’t like talking, or I was in a quiet place such as a library”. These responses of non-Virtual Human participants indicate that they would like to have a manual input rather speech input. However, for participants in a Virtual Human condition would like to have variation in the questionnaire.

In response to the question, “Do you think Iris meets your needs of physical and mental health self-management?”, mostly both the conditions gave similar responses, such as “Yes, she asks about my health and makes me aware of how to take care of it in a better way”, “Yes, because it works as an assistant for self-introspection of myself. Also, it reminds me if I am forgetting to do anything like exercise or skipping a meal”, “Yes, Iris meet my need sufficiently by asking me health questions on a daily basis and remind me to do the regular physical activity”, “Yes, It reminds me to take part in mental and physical activities by sending notifications”. Only one non-Virtual Human condition participant said, “No. It does not give statistics to track and improve.” Except for one non-Virtual Human participant, all participants gave positive responses. This indicates that Iris meets the need of health management for the participants.

In response to the question, “In general, how do you think Iris will help you manage your health?”, in both, the conditions participants give similar responses, such as “Regular reminder to interact with the app to meet your daily essential activities, may it be physical or mental”, “I am not sure about it since I have not seen the results or any interventions with the information that I mentioned from day to day. If there was some way I could have seen the results at that instant or some trends or what would be done with the information that is being collected, it would have been more helpful”, “I think it is going to help if it provides ways to improve”, “documentation can be helpful to track my progress over time. motivating quotes are also helpful”. These results in both conditions indicate that there is a need for feedback on responses. Iris will be more useful is she can get the feedback from users’ caregivers, which is not the case in our study.

In response to the question, “Do you have any recommendations for improving iHeartU?”, the non-Virtual Human conditions participants said, “I think in every question there should be an option of manually answering a question, this doesn’t mean that the listening or understanding capability of the app is bad but it’ll be an add-on and sometimes an easy option to operate the app”, “Add interaction keys like yes/no for one-word answers and record audio for rest and speed up the process and gets as much information as needed.”, “It feels robotic, it needs to be more natural and interactive.”, “Change the voice”, “add buttons to type answers, along with the voiceover”, “It is taking more time to speak the questions. instead, just the sentences on the screen can be enough to answer”. In responding to the same question, Virtual Human condition participants said, “The question should be asked in a random order and should not repeat the same question at two different times in a day”, “Iris can keep a track of my daily meals and exercise and avoid asking the same questions again and again. Also, the record can be maintained for a week”, “I like the app. The visuals realism is life like. It's a good user-friendly app overall”, “Make it more detailed”. These responses indicate that participants in the Virtual Human condition want to use the application and provide suggestions for its improvement, while participants in the non-Virtual Human condition prefer a typical GUI interface instead of using speech-to-text.

Discussion

After evaluation and getting feedback from the participants, it can be inferred that participants in the NVH condition tend to lose interest in using the app over a longer period of time since there is a significant decrease in the total number of session completed in NVH condition in following week than in the first week. However, the participants in the VH condition showed a nearly constant number of sessions over the period of three weeks.

The significant increase in the number of questions answered in the VH condition in following week than in the first week shows that users tend to use the app more seriously and try to answer more questions. This significant result and the qualitative responses of participants: where the NVH condition participants asked for manual input option instead speech input and a textual interface over voice output, indicates that users will accept the virtual human based health monitoring application if they can get feedback for their responses.

We also discovered that it is important to show a graph or any kind of trends that will help them to track their health. It also makes sense when people say that they don't what a repetitive question every day. For instance, people who do not even know anything about yoga will get frustrated if they are asked about that every day. The questions should be customizable and should be uniquely created for the user. So, in the real scenario when there is a caregiver monitoring their responses this could be useful because they will get the customized questions and will also get feedback for their responses.

CHAPTER SIX

COCLUSION AND FUTURE WORK

Conclusion

To our knowledge, this research is one of the first in empirically examining the impact of Virtual Human (VH) interface over the non-Virtual Human (NVH) interface in a healthcare domain on a mobile platform over a period of three weeks. We developed an Android application for healthcare monitoring and assistance by integrating various technology such as speech recognition, text-to-speech, and audio input, for investigating the extent different interfaces affected users in their usability aspect and on their behavioral awareness.

The current study is a preliminary presentation of a current ongoing investigation. The current work shows the trends and provides insights on the direction this investigation might end. In our empirical evaluation, we found that participants in a VH condition tend to constantly use the app while participants in NVH condition tends to lose interest. The significant decrease in the number of sessions completed by participants in the NVH condition is a clear indication of this.

Currently, there are commercial versions that incorporate virtual human based interfaces for healthcare on a mobile platform, but there is no study to discuss there impact, however, we did not find any application who incorporated virtual human-related features to the extent we did, such as nonverbal behavior which is incorporated through facial expressions and animations.

The qualitative responses of participants showed that users' in the virtual human condition felt more engaged during the interaction. They referred to the character of the app as "caring", "friendly" and "motivating" while non-Virtual Human version users referred to as "Robotic".

However, even though a significant effect was found on the user's perceived stress questionnaire, we feel this trend is not highly meaningful since behavioral change demands longer periods of time.

We had the limitation of considering participants in the study. We could only consider participants who had a very good with high computation power Android smartphones. This is the main cause for the lack of power in the study.

Future Work

To take this research forward, we plan to gather more participants to have more statistical power and to reach to the trends we observe in the current analysis results. We would also want to recruit real patients to examine the impact of Virtual Human (VH) interface in the health monitoring application.

Also, we believe that our future investigation would involve the consequence that different fidelities of animation have over the user usability.

Finally, once we recruit a participant pool with possibilities to establish more precise conjectures, we expect to submit this investigation to prestigious conferences such as Intelligent Virtual Interfaces or IEEE VR.

APPENDICES

Appendix A

iHeartU Questionaire and Conversational script

Have you had anything to eat in (eat_time)?

> T) What did you have in (eat_time)?
>
> F) Please be sure to eat three times daily.

What fluids have you had to drink since (time) and how much of each did you drink?

Now, I will ask you a series of questions about your physical activity.

Did you do any aerobic activity since (time)?

> T) What kinds of aerobic activity did you do?
>
> F) Remember, as an adult, you must do minimum of 150 minutes per week of moderate-intensity aerobic activity, like brisk walking

Did you do any muscle-strengthening activities since (time)?

> T) What kinds of muscle-strengthening activities did you do?
>
> F) Remember to do muscle-strengthening activities on at least 2 or more days a week that work all major muscle groups, like (legs, hips, back, abdomen, chest, shoulders, and arms)

Did you do any yoga or stretches since (time)?

> T) What kinds of yoga moves or stretches did you do?
>
> F) Practicing yoga once a week gives you time to focus on your breathing and become present.

Do you feel any tension or stress while doing mental work since (time)?

> T) Remember, one minute in meditation can have a frustrated, angry, or terrible-feeling person feeling resourceful, kind, and fun.
>
> F) Great!

Do you feel any body aches or pains, fatigue, headache, or muscle weakness since (time)?

> T) Can you please describe them for me?
>
> F) Okay, good! Remember to always alert your doctor immediately if you feel any of these symptoms.

Do you have anything else you would like me to be aware of?

> T) Okay, what exactly is worrying you?

F) Okay, please keep me informed if you experience any unexpected symptoms.

Do you feel alone or stressed out?

T) You should seek help from a partner, family member, friend, counselor, doctor, or pastor. Having someone with a sympathetic, listening ear and talking about your problems and stress can really lighten the burden.

F) Great! Remember, the best way to handle this is to seek the company of family and friends with whom you can share your problems.

Do you do any fun activities such as: watching a movie, listening to music, or playing your favorite sports?

T) Great!

F) You can take your mind off of your problems with such activities.

Taking part in such activities is a positive way to reduce stressful feelings.

Appendix B

Demographics questionnaire

Instructions: Please answer the following questions about you.

Please Circle All That Apply

1. What is your sex? Male Female

2. What is your age?

   18-24 Years 25-30 Years
   31-40 Years 61-70 Years
   41-50 Years 71-80 Years
   51-60 Years
   81-90 Years Other

3. What is your race?
   White Native Hawaiian or other
   Pacific Islander
   Black or African-American American Indian or Alaska
   Native
   Hispanic Some other race (please
   list) _________
   Asian

4. Do you play video games?
   ☐ Yes ☐ No

5. On average, how many hours a week do you think you spend playing video games (mobile or other)?
   ☐ 0 ☐ 1-2 ☐ 3-5 ☐ 6-9 ☐ 10+

6. List three things you like to see when playing a video game.

7. On what platforms do you play video games on? (Check all that apply)

8. What sort of games do you play?

☐ First Person Shooter (FPS)
☐ Action/Adventure
☐ Puzzle
☐ Educational
☐ Multiplayer Online Battle Arena (MOBA)
☐ Role-Playing (RPG)
☐ Simulation
☐ Strategy
☐ Sports
☐ Other ___________________________

9. How long are your gaming sessions? (Please check ONE)

☐ Under 30 minutes

☐ 30 min - 1 hour

☐ 1 hour - 2 hours

☐ 3 or more hours

10. How/Why do you play games? (Select what best applies)

☐ To kill time (On the bus, waiting for something, etc.)
☐ Recreation/Entertainment
☐ Social Gaming (Playing games as a way to hand out and spend time with friends)

11. Generally speaking, do you play more games with online multiplayer available?

☐ Yes, and I play in multiplayer mode
☐ Yes, but I do not play in multiplayer mode
☐ No, I mostly do not play games with multiplayer mode included

12. What is your social online play style?

☐ In PUBLIC matches/servers, with clan, guild members, friends or family

☐ In PRIVATE matches/servers, with clan, guild members, friends or family
☐ In PUBLIC lobby or server without a party
☐ I do not play online enough to answer

13. If you do play online, do you use a headset/microphone to communication with other players?

☐ Yes, I use my headset to listen and speak with other players
☐ Yes, but I only communicate with people I already know and/or mute all other players
☐ No, I do not use a headset to listen and/or communicate with other players
☐ I do not play online

14. Do you regularly use a smartphone (e.g., iPhone or Samsung Galaxy or Google Nexus or similar)?
    Yes
    No

15. What brand of smartphone do you use?

16. How long have you owned your smartphone?
    ____________ years
    ____________ Not applicable

17. For which of the following activities do you ever use your <u>mobile phone</u> for? (Check all that apply)

Phone calls	Exercising
Text messaging	Social networking (e.g., Facebook)
Shopping	Navigating with maps (e.g., finding a store)
Banking	Entertainment (e.g., movies, games)
Emailing	Other ___________________________

18. Please list the applications that you use to track your personal health measures:

Appendix C

Eating disorder Questions

Q1 Do you make yourself Sick because you feel uncomfortably full?

- ◯ Yes (1)
- ◯ No (2)

Q2 Do you worry you have lost Control over how much you eat?

- ◯ Yes (1)
- ◯ No (2)

Q3 Do you worry you have lost Control over how much you eat?

- ◯ Yes (1)
- ◯ No (2)

Q4 Have you recently lost more than One stone (6.35 kg) in a three-month period?

- ◯ Yes (1)
- ◯ No (2)

Q5 Do you believe yourself to be Fat when others say you are too thin?

- ◯ Yes (1)
- ◯ No (2)

Q6 Would you say Food dominates your life?

- ◯ Yes (1)
- ◯ No (2)

Appendix D

Physical Activity Survey

DETERMINANTS OF BODY FATNESS IN YOUNG ADULTS LIVING IN A DUTCH COMMUNITY

1. Questionnaire, codes and method of calculation of scores on habitual physical activity
2. What is your main occupation?
3. At work I sit
    a. never/seldom/sometimes/often/always
4. At work
    a. I stand never/seldom/sometimes/often/always
5. At work I walk
    a. never/seldom/sometimes/often/always
6. At work I lift heavy loads
    a. never/seldom/sometimes/often/very often
7. After working I am tired
    a. very often/often/sometimes/seldom/never
8. At work I sweat
    a. very often/often/sometimes/seldom/never
9. In comparison with others of my own age
    a. I think my work is physically much heavier/heavier/as heavy/lighter/much lighter

9) Do you play sport?
yes/no
If yes: - which sport do you play most frequently?
how many hours a week?
how many months a year?
I f you play a second sport:
which sport is it ?
how many hours a week?
how many months a year?

10.) In comparison with others of my own age I think my physical activity during leisure time is
    a. Much more/more/the same/less/much less
11. During leisure time I sweat
    a. very often/often/sometimes/seldom/never
12. During leisure time I play sport
    a. never/seldom/sometimes/often/very often

13. During leisure time I watch television
    a. never/seldom/sometimes/often/very often
14. During leisure time I walk
    a. never/seldom/sometimes/often/very often
15. During leisure time I cycle
    a. never/seldom/sometimes/often/very often
16. How many minutes do you walk and/or cycle per day to and from work, school and shopping?

Appendix E

Social Presence Questions

Factor Items Factor Loading

______________ Co-presence (M=4.72, SD=0.83) α = .84

1. I noticed Iris
2. Iris noticed me.
3. Iris presence was obvious to me.
4. My presence was obvious to Iris.
5. Iris caught my attention.
6. I caught Iris attention.

______________ Attentional Allocation (M=4.58, SD=1.00) α = .81

7. I was easily distracted from Iris when other things were going on.
8. Iris was easily distracted from me when other things were going on.
9. I remained focused on Iris throughout our interaction.
10. Iris remained focused on me throughout our interaction.
11. Iris did not receive my full attention.
12. I did not receive Iris full attention.

______________ Perceived Message Understanding (M=4.78, SD=0.90) α = .87

13. My thoughts were clear to Iris
14. Iris thoughts were clear to me.
15. It was easy to understand Iris.
16. Iris found it easy to understand me.
17. Understanding Iris was difficult.
18. Iris had difficulty understanding me.

______________Perceived Affective Understanding (M=3.72, SD=1.14) α = .86

19. I could tell how Iris felt.

20. Iris could tell how I felt.

21. Iris emotions were not clear to me.

22. My emotions were not clear to Iris.

23. I could describe Iris feelings accurately.

24. Iris could describe my feelings accurately.

______________ Perceived Emotional Interdependence (M=3.62, SD=1.06) α = .85

25. I was sometimes influenced by Iris moods.

26. Iris was sometimes influenced by my moods.

27. Iris feelings influenced the mood of our interaction.

28. My feelings influenced the mood of our interaction.

29. Iris attitudes influenced how I felt.

30. My attitudes influenced how Iris felt.

______________Perceived Behavioral Interdependence (M=4.32, SD=0.91) α =. 82

31. My behavior was often in direct response to Iris behavior.

32. The behavior of Iris was often in direct response to my behavior.

33. I reciprocated Iris actions.

34. Iris reciprocated my actions.

35. Iris behavior was closely tied to my behavior.

36. My behavior was closely tied to Iris behavior.

Appendix F

Technology Acceptance questions

The self-designating opinion leadership scale25 consisted of six items:

i. During the past six months have you told anyone about some new technologies?

2. Compared with your circle of friends are you more likely to be asked for advice about new technologies?

3. Compared with your circle of friends are you less likely to be asked for advice about new technologies?

Thinking back to your last discussion about some new technologies

4. When you and your friends discuss new ideas about farm practices, what part do you play?

(a) Mainly listen or (b) try to convince them of your ideas?

5. Which of these happens more often,

(a) you tell your neighbors about some new farm practice, or (b) they tell you about a new practice?

6. Do you have the feeling that you are generally regarded by your neighbors as a good source of advice about new farm practices?

The opinion leadership scale actually deals with two components of opinion leadership

(i) the respondent's self-image as an opinion leader, and (2) the respondent's perception of past behavior when interacting with others. Questions 2, 3, and 6 deal with the respondent's self-image while questions 1, 4, and 5 measure the respondent's perception

of past behavior; nevertheless, a Guttman scale analysis yielding a coefficient of reproducibility of 91.4 indicates that these six items appear to measure a single dimension.

Appendix G

Usability questions

SUBJECTIVE SATISFACTION QUESTIONNAIRE

Based on: Lewis, J. R. (1995) IBM Computer Usability Satisfaction Questionnaires: Psychometric Evaluation and Instructions for Use. *International Journal of Human-Computer Interaction 7:1*, 57-78.

Participant #: ________

Instructions: Please rate the usability of the system. Try to respond to every item.

1. Overall, I am satisfied with how easy it is to use the IHeartU app.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

2. It was simple to use the IHeartU app.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

3. I can effectively complete my mission using IHeartU app.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

4. I am able to complete my mission quickly using IHeartU app.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

5. I am able to efficiently complete my mission using IHeartU app.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

6. I feel comfortable using IHeartU app.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

7. It was easy to learn to use IHeartU app.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

8. I believe I became productive quickly using this system.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

9. The IHeartU app gives error messages that clearly tell me how to fix problems.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

10. Whenever I make a mistake using IHeartU app, I recover easily and quickly.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

11. The information (help, on-screen messages, tool-tips, etc.) provided is clear.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

12. It is easy to find the information I need.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

13. The information provided by IHeartU app is easy to understand.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

14. The information is effective in helping me complete the tasks and scenarios.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

15. The organization of information on the IHeartU app screens is clear.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

16. The interface of IHeartU app is pleasant.

1	2	3	4	5

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

17. I like using the interface of IHeartU app.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

18. The IHeartU app has all the functions and capabilities I expect it to have.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

19. Overall, I am satisfied with the IHeartU app.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

20. I am confident about the results I produced.

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

Appendix H

International Personality Item Pool Interpersonal Circumplex Survey

Answer the following questions on the below scale:

1-Very inaccurate 2-Moderately inaccurate 3-Neither inaccurate nor accurate

4-Moderately accurate 5-Very accurate

	Questions	Response
1.	Am quiet around strangers	
2.	Speak softly	
3.	Tolerate a lot from others	
4.	Am interested in people	
5.	Feel comfortable around people	
6.	Demand to be the center of interest	
7.	Cut others to pieces	
8.	Believe people should fend for themselves	
9.	Am a very private person	
10.	Let others finish what they are saying	
11.	Take things as they come	
12.	Reassure others	
13.	Start conversations	
14.	Do most of the talking	
15.	Contradict others	
16.	Don't fall for sob-stories	
17.	Don't talk a lot	
18.	Seldom toot my own horn	
19.	Think of others first	
20.	Inquire about others' well-being	
21.	Talk to a lot of different people at parties	
22.	Speak loudly	
23.	Snap at people	
24.	Don't put a lot of thought into things	
25.	Have little to say	
26.	Dislike being the center of attention	
27.	Seldom stretch the truth	
28.	Get along well with others	
29.	Love large parties	
30.	Demand attention	
31.	Have a sharp tongue	
32.	Am not interested in other people's problems	

Appendix I

Public health questions

Over the last 2 weeks, how often have you been bothered by any of the following problems? *(Use "✔" to indicate your answer)*	**Not at all**	**Several days**	**More than half the days**	**Nearly every day**
1. Little interest or pleasure in doing things	0	1	2	3
2. Feeling down, depressed, or hopeless	0	1	2	3
3. Trouble falling or staying asleep, or sleeping too much	0	1	2	3
4. Feeling tired or having little energy	0	1	2	3
5. Poor appetite or overeating	0	1	2	3
6. Feeling bad about yourself — or that you are a failure or have let yourself or your family down	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed? Or the opposite — being so fidgety or restless that you have been moving around a lot more than usual	0	1	2	3
9. Thoughts that you would be better off dead or of hurting yourself in some way	0	1	2	3

FOR OFFICE CODING ___*0*___+________+_________+ ________

=Total Score: ________

If you checked off any problems, how difficult have these problems made it for you to do your work, take care of things at home, or get along with other people?

Not difficult at all	Somewhat difficult	Very difficult	Extremely difficult
☐	☐	☐	☐

Appendix J

Qualitative Questions

1. How would you describe Iris's personality?

2. What is your most favorite feature that Iris/this app has? (probe: explain)

(What aspects of the iHeartU did you like the most?)

3. What aspects of this app did you not like so much?

4. Do you think Iris meet your needs of physical and mental health self management?

(probe: if yes, why; if not why?)

5. In general, how do you think Iris will help you manage your heath?

6. Do you have any recommendations for improving the iHeartU? (I.E. natural dialogue, more in-depth and open conversations with Iris, changing the virtual companions clothing and

appearance, improving her visual realism, etc)

Appendix K

PERCEIVED STRESS SCALE

The questions in this scale ask you about your feelings and thoughts during the last month**. In each case, you will be asked to indicate by circling *how often* you felt or thought a certain way.**

Name ______________________________ Date ____________

Age ________ Gender (*Circle*): **M F** Other ____________________

0 = Never 1 = Almost Never 2 = Sometimes 3 = Fairly Often 4 = Very Often

1. In the last month, how often have you been upset because of something that happened unexpectedly?	0	1	2	3	4
2. In the last month, how often have you felt that you were unable to control the important things in your life?	0	1	2	3	4
3. In the last month, how often have you felt nervous and "stressed"?	0	1	2	3	4
4. In the last month, how often have you felt confident about your ability to handle your personal problems?	0	1	2	3	4
5. In the last month, how often have you felt that things were going your way?	0	1	2	3	4
6. In the last month, how often have you found that you could not cope with all the things that you had to do?	0	1	2	3	4
7. In the last month, how often have you been able to control irritations in your life?	0	1	2	3	4
8. In the last month, how often have you felt that you were on top of things?	0	1	2	3	4
9. In the last month, how often have you been angered because of things that were outside of your control?	0	1	2	3	4
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	0	1	2	3	4

Appendix L

IRB Approval

Information about Being in a Research Study
Clemson University

Health Companion App (IHeartU)

Description of the Study and Your Part in It
Dr. Sabarish Babu and Dr. Lingling Zhang are inviting you to take part in a research study. Dr. Babu is an Associate Professor in School of Computing in Clemson University. Dr. Lingling Zhang is an Assistant Professor in the College of Behavioral, Social and Health Science in Clemson University. Matias Volonte is a Ph.D. student in Human Centered Computing, Pratyush Singh is a Master student in Computer Science and Jenna Van Pelt is an Undergraduate student in Computer Science at Clemson University.

The purpose of this study is to investigate the extent an Android application can induce users' awareness about adopting to a healthier life-style. We believe that this Android application could be a good method for this purpose. The researchers will be happy to answer any questions for you. The researchers are not health care providers and will not use any of the results from the study to diagnose any illness or recommend treatment.

Your participation will involve:

1. Answering questions about your daily physical activity, eating behaviors (disorders) and mental status. Some sessions during this study will be audio and video recorded and stored in a secure location.
2. Using an Android app three times a day to answer your current deposition for three weeks.
3. You will be debriefed at the end of each week during the study.

Requirements
Participants need to be Android users.

Risks and Discomforts
Some of the questions in the surveys are of a personal nature and may be upsetting to some participants. The investigator will be available to discuss these questions should you have a concern or problem. You do not have to answer any questions that you do not want to answer.

Should you need to speak with someone, counseling and psychological care are available through Counseling and Psychological Services at Redfern Health Center, call (864) 656-2451. You may also consider the following confidential resources:

- Mental Health America of Greenville County's CRISIS line: 864) 271-8888. Free, 24/7 crisis phone line.
- Crisis Chat: http://www.crisischat.org/, free chat line available 2PM to 2AM, 7 days/week.
- Crisis Text Line: Text "START" to 741-741, service is free through most major phone service carriers and available 24/7.
- Contact a mental health professional of your choice, at your own expense.

CLEMSON

IRB Number: IRB2018-207
Approved: 6/1/2018
Expiration: 5/31/2019

Page 1 of 3

Possible Benefits
The medical field might benefit since this app can encourage users to incorporate a healthier lifestyle. Moreover, this research may help contribute to the broader questions of user interactions and behavioral patterns or changes noted in both virtual and real world environments. The results of this research may have an impact on how we look at exposure to virtual settings as a whole.

Incentives
You will be offered a $25 gift card upon completion of the experiment.

Protection of Privacy and Confidentiality
All survey data, video recordings, and other digital data will be stored on password protected computers, to which only researchers associated with this study have access. Identifiable information in the video or audio recordings will be removed (bleeped out) immediately after collection, before storage. Any paper or physical media will be stored in a locked cabinet. The results of this experiment will be summarized across all participants, and no information will be presented that may identify you specifically. Your identity will not be revealed in any publication that might result from this study. Video recordings from this experiment will not be shared publicly. The data will be stored for a period of 3 years. After the duration of approval of this study, all physical and digitized data will be destroyed.

We might be required to share the information we collect from you with the Clemson University Office of Research Compliance and the federal Office for Human Research Protections. If this happens, the information would only be used to find out if we ran this study properly and protected your rights in the study.

Page 1 of 2

Choosing to Be in the Study
You do not have to be in this study. You may choose not to take part and you may choose to stop taking part at any time. You will not be punished in any way if you decide not to be in the study or to stop taking part in the study. If you choose to stop taking part in this study, the information you have already provided will be used in a confidential manner.

Contact Information
If you have any questions or concerns about this study or if any problems arise, please contact Matias Volonte at Clemson University at volontematias@gmail.com.

If you have any questions or concerns about your rights in this research study, please contact the Clemson University Office of Research Compliance (ORC) at 864-656-0636 or irb@clemson.edu. If you are outside of the Upstate South Carolina area, please use the ORC's toll-free number, 866-297-3071.

CLEMSON

IRB Number: IRB2018-207
Approved: 6/1/2018
Expiration: 5/31/2019

Consent

By signing this consent form, you indicate that you have read the information written above, are at least 18 years of age, been allowed to ask any questions, and are voluntarily choosing to take part in this research. You do not give up any legal rights by signing this consent form.

Participant's signature: ________________________________ Date: _______________

Print name of participant: _____________________________

A copy of this form will be given to you.

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